ENHANCING VALUE MANAGEMENT WITH BUILDING INFORMATION MODELLING IN CONSTRUCTION INDUSTRY

LUA XIN CHUN

UNIVERSITI TUNKU ABDUL RAHMAN

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LUA XIN CHUN

A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying

Lee Kong Chian Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature :

Name : LUA XIN CHUN

ID No. : 20UEB03399

Date : 18.05.2024

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"ENHANCING VALUE MANAGEMENT WITH BUILDING INFORMATION MODELLING IN CONSTRUCTION INDUSTRY"** was prepared by **LUA XIN CHUN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying at Universiti Tunku Abdul Rahman.

Approved by,

Signature :

Supervisor : Sr LI ZI QIAN

Date : 19 May 2024

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ABSTRACT

The construction industry is crucial for driving economic and supporting social stability growth in the Malaysian economy. Currently, the industry often encounters challenges such as substandard quality, ineffective communication, cost overruns and project delays. These problems are becoming increasingly common and have a significant impact on construction projects. Value management (VM) is considered as a key strategy to address these issues, while Building Information Modelling (BIM) is one of the most effective and accurate media for obtaining basic and specific project data required for the VM process. However, the previous studies mainly focused on the use and impact of BIM and VM respectively. Hence, this research aims to examine the enhancement of VM with BIM in the construction project. The objectives are to identify the advantages incurred from the enhancement of VM with BIM, to investigate the barriers to using BIM to enhance VM and to propose strategies to disseminate the use of BIM to enhance VM. This study adopted a quantitative research method using a questionnaire survey with the participation of 132 construction practitioners with experience in VM or BIM. Thirteen advantages, eight barriers, and seven strategies for enhancing VM with BIM were reviewed from the literature. The survey revealed that the top 3 most recognised advantages include better choices and optimized project outcomes, improved collaboration and communication among project stakeholders, and improved work productivity and quality. Meanwhile, the 3 primary barriers that undermine the enhancement of VM with BIM are high implementation costs, industry resistance to process change and lack of skill and training. It is also found that the respondents who work for property development companies and large-sized firms are more inclined to acknowledge the barriers that hinder the enhancement of VM with BIM. Additionally, the three most effective strategies to enhance VM with BIM are providing professional training and promotion plans, establishing a start-up funding mechanism, and including VM clauses and BIM in contracts. A strong correlation is found between the high cost of implementation and establishing a start-up funding mechanism, as well as lack of standardization and standardized BIM implementation process, while there is an inverse relationship between cooperation with educational institutions and industry resistance to process change, as well as the establishment of a start-up funding and lack of interoperability and data exchange. This study concluded that there is a room to improve the adoption of VM with BIM in the construction industry, by leveraging different strategies.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In 2022, the gross domestic product (GDP) of Malaysia grew significantly by 8.7%, compared to the 3.3% growth the year before. Additionally, the construction sector rebounded strongly, growing by 5.0% in 2022 after experiencing a decrease of 5.1% in the previous year. Therefore, the construction industry in Malaysia plays an important role in the Malaysian economy, accounting for 5% of the GDP annually (DOSM, 2023).

Lin et al. (2023) perceived that the construction industry plays an important role in stimulating economic growth and supporting social stability, and is often used by developing countries as a platform to stimulate economic transition to developed countries. However, Olanrewaju et al. (2022) perceived that construction projects in these nations usually run into a variety of problems, including non-completion, schedule postponements, overspend, low standards, and a high probability of failing to accomplish the stated objectives. In addition, the increase in demand for construction projects has brought about increased competition among construction companies, leading to the possibility of problems with project value (Baarimah et al., 2021).

To address these challenges and maximize the value delivered by construction projects, value creation initiatives such as Value Management (VM) can be considered as a strategic approach. VM is described as a team-oriented analytical procedure that facilitates the functional analysis of systems to maximize value over the project lifecycle (Punnyasoma et al, 2019). It should be applied from the planning stage as the key factor in implementing VM is efficient use of limited time and resources to deliver optimal results (Annamalai and Ganapathy, 2021)

Aghimien and Oke (2015) mentioned that VM was emerged in the United States in the 1940s and first applied to construction projects in the 1960s. The scarcity of resources and materials during World War II led to the development of methods to identify cost-effective alternatives without compromising performance. Furthermore, construction projects in developed nations like the United States and the United Kingdom frequently employ VM practises (Lin et al., 2023). While the U.S. government requires VM for any public project costing more than $2 million, as well as any transportation-related projects, with thresholds as low as $100,000. As a result, VM has developed into a well-known service, providing universally recognised tools, techniques and styles for a wide range of construction projects in the UK. However, in Malaysia, the government enforces VM for public projects costing more than RM50 million (CIDB, 2022). Therefore, VM is rarely adopted in most of the construction projects in Malaysia, as relatively high-cost projects only account for a small portion of the industry.

At the same time, Building Information Modelling (BIM) represents a transformative approach for the architecture, engineering and construction (AEC) industry. It empowers AEC professionals to make informed decisions at every stage of a project, resulting in better planning, design, construction and maintenance outcomes (Fadeyi, 2017). It provides a variety of substantial advantages to the construction projects, such as better assess of time and costs associated with structural modifications, support for supply chain performance throughout teams and project phases, and improve risk sharing among professionals (Olanrewaju et al., 2022).

The use of BIM is gaining popularity among construction professionals worldwide. The United Kingdom, Canada, Finland, and New Zealand have extensive BIM knowledge. As a result, BIM adoption and expertise have significantly increased, from 10% in 2011 to over 70% in 2019 (Olanrewaju et al., 2022). However, the current level of BIM adoption in Malaysian construction sector is relatively low because BIM is still being implemented in the early phases in the country. In Malaysia, the application of BIM in the design phase is more in the modeling part, and it has not been implemented in the construction phase. This has resulted in a delay in BIM adoption, keeping the industry's level of BIM implementation low (Othman et al., 2021).

Nonetheless, under the "National Construction Policy 2030", the construction industry in Malaysia is currently undergoing a transition towards technology adaptation and adoption as part of the Industrial Revolution (IR) 4.0. By the year 2030, it is anticipated that at least half of the sector's processes will be digitized, including procurement and monitoring phases. These phases are expected to be fully automated with the adoption of BIM as an integrated and comprehensive approach to infrastructure construction. This encompasses the pre-design stage, construction phase based on agreed designs, and maintenance phase upon completion of the infrastructure for occupancy. The policy aims to adapt to the requirements of technology and innovation to further promote the use of BIM within the Malaysian construction sector (Kementrian Kerja Raya., n.d.).

In addition, the “Construction 4.0 Strategic Plan 2021-2025” is designed to guide collaboration between the government, industry, and academia in cope with the rapid changes brought about by the IR4.0 in the construction sector. It serves as a roadmap for transforming the Malaysian construction industry by developing comprehensive Strategic Plans. By integrating the five core values of Construction 4.0—well-being, productivity, sustainability, integrity, and safety and health—it offers a holistic approach to future development. BIM is an integral part of Construction 4.0, where simulation and modeling play a key role. Leverage simulation to enhance operations and reduce risk given the unique complexities and external impacts of construction projects. At the same time, BIM provides a variety of simulation tools for project planning, resource allocation, and project management (CIDB, 2020).

While VM and BIM each have significant benefits, using BIM to enhance VM can amplify the benefits of each and deliver optimal value throughout the project lifecycle. Moreover, Punnyasoma et al. (2019) studied the ability of BIM to improve the efficiency of VM processes in Sri Lanka, thereby increasing the value delivered to customers. BIM is considered one of the most efficient and accurate media for obtaining the fundamental and specific project data required for the VM process. Therefore, enhanced VM through BIM has the potential to facilitate value-driven continuous improvement.

1.2 Problem Statement

According to Othman et al. (2021), traditional processes have an impact on the construction sector in Malaysia, which leads to delays, cost overruns, poor quality, poor performance, and low productivity. In addition, Tang and Liu (2022) mentioned that the requirements of modern construction project management can no longer be addressed by traditional construction management practises and information transmission mechanisms. Furthermore, the construction industry frequently has "adversarial relationships" and a "lack of trust" among all of the relevant parties because of the complex structure and multiple parties involved. This culture frequently causes waste, delays, rework, and inefficiencies (Celik et al., 2023).

Different approaches including VM have been proposed to address the problems. VM aims to maximise the project's functions at the lowest possible overall cost and give the client the best result and value for their money. VM involves the efforts of a multidisciplinary team to generate innovative ideas or alternatives (Lin et al., 2023). Although the benefits of VM are widely recognised, several limitations have also been identified. VM in its traditional form may struggle to visualize the full scope and impact of potential changes. In addition, the VM processes often rely on incomplete or outdated information, leading to suboptimal decision-making. (Fadeyi, 2017). The critical success of VM relies on the seamless coordination and effective communication between various stakeholders. Without it, the collaboration can be fragmented. BIM is one of the most fitted approaches that can fill in the gaps and meet the purpose.

Therefore, BIM can enhance multidisciplinary collaboration in VM Team as it provides information exchange and interoperability among stakeholders (Othman et al., 2021). It improves project efficiency by simulating construction processes, guiding sequencing and resource allocation, aids in cost estimation and enables stakeholders to make better choices regarding project budgets (Olawumi and Chan, 2018). Therefore, the enhancement of VM with BIM is effective because BIM collaborative capabilities align with VM's emphasis on multidisciplinary teamwork and value optimization. Despite the numerous potential benefits of using BIM to enhance VM, the implemention may face barriers such as lack of awareness, interoperability issues, resistance to change, and limited skills (Chan et al., 2019).

Over the past decade, numerous studies on projects combining BIM and Value Engineering (VE) have been conducted to investigate a range of factors that may positively or negatively affect construction projects. For example, Barimah (2021) discusses the level of research on the integration of BIM and VE and provides recommendations for future research. Additionally, Wei and Chen (2020) study is about the integration of BIM and VE to improve green building design, which employed simulation to create a number of building envelope alternatives that promote effective energy consumption. Furthermore, Park et al. (2017) explored a strategy of integrating BIM with the VE Idea Bank. The proposed BIM-based Idea Bank can systematically manage VE data and generate new ideas. The results show that the Idea Bank has great potential to improve the efficiency of VE research. Thus, the existing research findings indicate that the majority of them largely concentrate on the pairwise cooperation between BIM and VE principles.

This is however, the present research and practical applications frequently focus on VM and BIM respectively, paying less attention to BIM's ability to improve the efficiency of VM processes (Punnyasoma et al., 2019). This fragmented approach may miss opportunities for value optimization, cost reduction, and stakeholder collaboration. Besides, the construction industry still lacks an understanding of how to leverage BIM to enhance VM practices, and lacks clear structures and guidelines to address the complexities of this implementation. This is because there is limited research on integrating VM with BIM concepts to solve construction issues.

Therefore, this study will further analyse how the usage of BIM affects the success of the VM process and encourages multidisciplinary collaboration between VM experts and BIM practitioners to maximize overall project outcomes. This can foster wider acceptance within the construction industry of adopting BIM to enhance VM and increase its implementation in construction projects.

1.3 Research Aim

The aim of the research is to examine the enhancement of VM with BIM in the construction project.

1.4 Research Objectives

The objectives of this research are:

i) To identify the advantages incurred from the enhancement of VM with BIM

ii) To investigate the barriers of enhancing VM with BIM.

iii) To propose the strategies on disseminating the enhancement of VM with BIM.

1.5 Research Methodology

Research methodology is the process of gathering information and data to conduct research. Research methodologies are divided into qualitative methods and quantitative methods. To accomplish the research's objectives, a quantitative approach was adopted for this research.

Examining the findings and content of all readings allows for a literature review, which improves comprehension of the topic of this study. Reviewing journals, articles, conference papers, websites, books, and earlier papers addressing the most recent studies on the enhancement of VM with BIM in the construction project served as the basis for the literature review.

This study adopts a quantitative approach by distributing questionnaires to collect data on the targeted-respondents. Table 1.1 shows a summary of the approaches applied to achieve each study objective.

Table 1.1: Summary of Approaches Used

Literature Review		
Questionnaire Survey and Data Analysis		
Objective 1:	**Objective 2:**	**Objective 3:**
To identify the advantages incurred from the enhancement of VM with BIM	To investigate the barriers of enhancing VM with BIM	To propose the strategies on disseminating the enhancement of VM with BIM.

1.6 Scope of the Study

The scope of the study emphasises on the enhancement of VM with BIM. This study was limited to participants who are currently working in construction industry and have experience or relevant knowledge in adopting VM or BIM, as they are able to provide reliable input and contribute to this study.

1.7 Outline of the Report

This study consists of five chapters: Introduction, Literature Review, Research Methodology, Results and Discussion and Conclusion and Recommendations.

Chapter 1 presents of the background of the study and the problem statement of the enhancement of VM with BIM. The aim and objectives of the study, research methodology and chapter outline are also provided in this chapter. The research scope was limited to construction professionals involved in VM practice or BIM implementation as respondents by using the quantitative research method.

Chapter 2 is the literature review of the study which provides an overview of the enhancement of VM with BIM. Next, the enhancement of VM with BIM and its benefits during the project life cycle will be covered. This chapter will explain the barriers of the enhancement of VM with BIM, followed by the strategies on disseminate the enhancement of VM with BIM.

Chapter 3 introduces the research methodologies for gathering data and information from the intended respondents. This chapter will cover justification of selected research philosophy and research method for this study, followed by research design. Next, a detailed justification and explanation of the questionnaire design is included in this chapter. The selected sampling and data analysis methods are discussed.

Chapter 4 examines and assesses the findings from the questionnaire survey administered to selected participants. Next, the significant findings gathered from the research data are discussed and evaluated against the aims and objectives of the study to achieve the ultimate objectives.

The final chapter of the study is Chapter Five. This chapter summarizes the aims of the study and achievement of the three research objectives. Besides, it covers the implications, limitations, and recommendations of the research to provide insightful information to upcoming investigators looking into related fields.

1.8 Summary

This research is to determine the enhancement of VM with BIM. The background of the study is outlined and the problem statement is defined. Each section of the chapter clearly states the aims and objectives, scope and methodology of the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will be reviewed by a series of articles, journals and academic books which are related to the using BIM to enhance VM in the construction industry. The overview of VM and the background of BIM will be discussed in the following subsections. Next, the Enhancement of VM with BIM in the Project Lifecycle will be described briefly. In addition, the advantages and barriers in Enhancing VM with BIM and strategies on disseminating the enhancement of VM with BIM will be identified.

2.2 Overview of VM

VM is a structured methodology employing a diverse team approach, systematic processes, and efficient outcomes (CIDB, 2022). Lin et al. (2022) perceived that value is the balance between what can be gained (such as an advantage, benefit, or positive outcome) and what has to be provided (such as a fee, investment, or resource).

According to CIDB (2022), VM emphasises the realization of the best value and continuously improves the value provided to customers over the duration of a project. The purpose of VM is to increase the value of all programmes, projects, structures, systems, products, and services while seeking to reduce their cost. As a result, the primary goal of VM is to enhance the value of a project through multidisciplinary team exercises by providing options to optimize project functionality and cost while maintaining quality and performance standards (Lin et al., 2022).

Furthermore, Punnyasoma et al. (2019) stated that VM has become a popular tool in the modern construction industry. This is because VM is a strategic tool and process aimed at optimizing the operational value of a project by managing its concept and design while analyzing customer-specified value system decisions (Alsolami, 2022). This approach is particularly valuable for addressing challenges such as budget limitations and uncertainties in construction projects. Besides, VM in construction is often concerned with cost, functionality, quality and durability constraints (Punnyasoma et al., 2019). Therefore, each action and component involved in the construction process needs to be determined and given an early estimate as to its function, duration, quality, and cost.

In contrast, Baarimah (2021) perceived that VE is an approach of cost reduction that is frequently used in the manufacturing and construction sectors as it provides cost-effective solutions to increase the value, effectiveness and utility of projects. For instance, there are several applications for VE in construction projects, including as functional analysis, cost control for new projects and materials, and evaluation of green stuctures to lower construction and energy costs. Hence, VE is one of the effective management strategies in the construction industry, which is used to enhance project functionality and eliminate unnecessary costs (Park et al., 2017).

In addition, Youssef (2023) mentioned that VE can be used to define the project's scope, facilitate informed choices, and improve the performance and quality of the project. It creates value for money at minimum cost, reliability and quality. The features of VE are function orientation, value enhancement, and cost-effectiveness. For example, the alternatives for each project item are specified in the VE task plan, designed to minimise costs and maximize benefits, while still performing the same functions at a similar or higher level than the original project idea.

Furthermore, Value Assessment or Value Planning (VP) refers to more strategic research involving the processes used to establish, clarify, and agree upon client's objectives during the early conceptual design stage of a project (Annamalai, 2021). The VP process goes from inception to program design completion. Additionally, CIDB (2022) stated that VP is used as one of the management tools to get value for money by determining project cost constraints and verifying actual requirements (or scopes of the projects). Therefore, the anticipated project outcomes and project objectives can be described in detail and prepared for potential delivery.

In addition, Annamalai (2021) claimed that Value Analysis (VA), also known as Value Review, is one of the most important techniques and an innovative approach to cut unnecessary costs. VA focuses on the post-occupancy evaluation procedure. It aims to achieve cost reduction without compromising essential attributes such as quality, reliability, performance, and appearance. This ensures that the final product or project maintains its intended functionality and meets stakeholder expectations.

2.3 What is BIM?

As BIM adoption continues to grow, it is becoming standard practice in the AEC industry. It involves creating digital models that replicate both the physical attributes and functional aspects of a facility. It is also referred to as a shared knowledge resource for facility data that offers a trustworthy foundation for choices at every stage of the facility's life cycle (Raza et al., 2023).

In addition, Punnyasoma et al. (2019) claimed that BIM is a digital representation and information management tool that encompasses various aspects of a building's lifecycle, from its initial planning and design stages through construction, operation, and maintenance. This is because BIM represents the constructed environment of the building on a virtual platform, and at the same time has the capacity to collect, manage, and organise a large amount of built environment-related data. BIM digitally shows a building's structural details and operational features. In addition, Chatzimichailidou and Ma (2022) mentioned that BIM is a computer-aided modeling and simulation technology that covers information in various dimensions beyond 3D geometry. Upgrading 3D models to fourth, fifth, and even sixth dimensions is a continuous process.

According to Fadeyi (2017), BIM includes virtual modelling, virtualization of building circumstances and attributes connected to its site location, model drilling, prefabrication, and conflict detection data for building systems. BIM 4D facilitates project planning, scheduling and management by considering 3D information from a temporal perspective, helping project stakeholders to visualize and simulate construction processes over time. Besides, 5D Dimensions integrates cost-related data with 3D models, enabling real-time cost estimation and budgeting throughout the project lifecycle. BIM 6D contains all of the data that was generated during the construction delivery process.

Likewise, BIM software from various providers, such as Autodesk, Bentley, and Graphisoft, allows architects, engineers, contractors, and other stakeholders to assist in the creation and management of these multidimensional models. Due to its simulation and visualization capabilities, the utilization of BIM has notably enhanced stakeholder collaboration within the construction industry, leading to enhanced operational efficiency (Chatzimichailidou and Ma, 2022).

Furthermore, the implementation of BIM in the construction industry has resulted in significant improvements across the entire project lifecycle, from initial planning to eventual recycling or disposal. By offering a centralised, reliable, and constant source of information throughout the project lifecycle, BIM encourages effective cooperation and knowledge sharing among all parties involved across disciplines. This makes it easier to retrieve project data for tasks like design, data management, modelling, and work scheduling (Celik, 2023).

In addition, Waqar et al. (2024) mentioned that BIM is a fast developing collaborative instrument that enables the integration of design and construction management. Its ability to create multi-dimensional models encompasses vital project aspects such as spatial planning, schedules, costs, materials, complex designs, manufacturing insights, and finishing details. It also realize dynamic real-time collaboration by facilitating information exchange among stakeholders. As a result, BIM helps identify potential issues early, reducing the risk of design errors, construction delays, and costly changes.

Moreover, Fu (2018) claimed that BIM is a method for organising and overseeing construction projects using 3D digital modelling. Every member of the design team creates and updates their own BIM model as part of a "central model." It is able to discover conflicts in the core model from several contributors. Therefore, BIM allows stakeholders to visualize and interact with a 3D model, providing a clearer understanding of design intent and project scope. Meanwhile, it can detect conflicts and clashes between different constrcution systems and components in the design process to avoid costly changes.

Nowadays, researchers are increasingly looking at how BIM may be used effectively in the various phases of construction. Therefore, many researchers suggest looking into the integrated use of BIM and other technologies in order to fully explore the enourmous potential of BIM in improving the construction process. By being completely integrated with other technologies at every step of the project lifecycle, BIM can evolve and contribute to future industry project performance (Meng et al., 2020).

2.4 Enhancing VM with BIM throughout the Project Lifecycle

VM is an effective approach for defining and optimising value for money. It aims to optimise its functionalities for a project at the lowest total cost in order to provide clients with the best benefits and value for their money (Lin, et al., 2023). However, many factors affect the characteristics of construction projects, making the cost and quality control more difficult. Therefore, using VM is not enough to effectively manage and control the cost and quality of construction projects.

As Baarimah, et al. (2021) mentioned that the construction industry has utilised BIM for a number of purposes, such as fostering collaborative interactions, minimizing costs and rework, elevating productivity, enhancing design excellence, facilitating seamless communication, aiding cost estimation, detecting clashes, expediting project timelines and more. As such, BIM has the potential to enhance VM practise at every construction delivery stages to achieve better outcomes, maximize value for stakeholders, and improve the overall project success (Punnyasoma et al., 2019).

2.4.1 Pre-Construction Stage

By incorporating BIM into the VM process, investors can enhance their ability to make informed investment decisions, optimize project value, and increase the accuracy of cost estimates. The investment decision-making stage is an important step in construction project, and the foundation for estimating the project's cost. Thus, accurate cost estimation is a key link in making correct investment decisions (Tang and Liu, 2022).

VM processes often suffer from relying on incomplete or outdated information, which can lead to less effective decision-making. According to

Olanrewaju et al. (2022), BIM may assist multidisciplinary culture VM team members and promote data exchange, which will aid in decision-making throughout project implementation. Data is considered information when it is gathered or recorded so that they can be used by decision makers involved in the construction delivery process (Fadeyi, 2017). For example, revising cost data, quantity data and information data analyzed from historical BIM databases to make informed program choices (Tang and Liu, 2022). Additionally, the model with a similar history can be modified and developed in order to calculate the cost and overall quantity of work for various cost programmes according to the programme characteristics of the new project. This enables correct decisions to be made and losses to be minimized because it is easier to compare and select investment options that provide the best value.

Furthermore, Punnyasoma et al. (2019) claimed that the problem statement for the value study preparation, which includes the strategic brief, project brief, and project aim, was identified during the pre-study phase. During the preparation stage, BIM serves as a centralised platform that makes it easy to obtain the most recent data and expertise needed for successful project delivery at various stages (Fadeyi, 2017). Poor communication and collaboration among VM stakeholders can lead to misunderstandings and misaligned objectives. By utilizing BIM as a centralised platform during the preparation phase, construction projects can benefit from improved communication, collaboration and data management in the VM processes.

2.4.2 Design Stage

By leveraging BIM during the design phase, VM can be improved by optimizing project value, making informed decisions, and ensuring that design choices align with project objectives and stakeholder priorities.

Fadeyi (2017) mentioned that the primary task during the design phase is to prepare design and construction instruction manuals. This is to maximize project value by assuring that the delivered building is feasible, sustainable, livable, functional, maintainable, and safe. Traditional VM practice rely on 2D drawings and documents can make it difficult for stakeholders to fully understand the design, leading to miscommunication and errors. In order to enhance VM process, BIM is utilized by engineers and architects to generate comprehensive 3D models before construction commences, which allows a more accurate and economical design process (Patel et al., 2023). Therefore, the 3D visualization capabilities of BIM help stakeholders better understand design intent and value-added features.

In addition, the collaboration between the Architect, Mechanical, Structural, and Electrical Engineers during the design stage, along with the use of BIM models and simulation software applications, brings significant benefits for evaluating building characteristics and sustainability (Olanrewaju et al., 2022). For example, BIM can be used to incorporate sustainable design principles into projects, including incorporating the value of green building features, renewable energy and adaptive design solutions. VM generally requires the involvement of various stakeholders, but the lack of an effective communication platform can lead to fragmented collaboration. BIM improves communication and collaboration by providing a shared, visually detailed, and data-rich environment for all parties involved.

Moreover, Olanrewaju et al. (2022) perceived that simulation software applications such as Ecotect and IES-VE (Integrated Environmental Solutions - Virtual Environment) are used to provide analysis and evaluation capabilities to assess building characteristics and sustainability factors. By importing BIM models into simulation software programmes, architects and engineers can gain insights into a variety of performance parameters, including as energy efficiency, thermal comfort, daylighting, and environmental effect. These simulations give them the flexibility to compare various design options and make informed decisions to optimize building performance and value.

Furthermore, Fadeyi (2017) claimed that BIM allows stakeholders to assess the project's design more accurately, visualize its impact on costs, and make informed design decisions. This enables decisions to be made that meet the goals and budget constraints of the project while maximizing value. BIM also serves as a valuable tool in this process by providing accurate, up-to-date data and enhancing collaboration between designers and cost engineers (Tang and Liu, 2022). Estimating costs accurately and managing budgets in VM practice can be challenging, often leading to cost overruns. Thus, they can use BIM to explore alternatives, brainstorm ideas, and identify areas where value can be increased without compromising quality. That is because project teams can improve design efficiency and ensure cost-effective decision-making by combining project visualization, design capabilities, and cost analysis within the BIM environment (Olanrewaju et al., 2022).

2.4.3 Construction Stage

Enhancing VM through BIM during the construction phase includes leveraging the capabilities of BIM to optimize construction processes, reduce costs, improve project coordination, and deliver maximum value. Strategies for utilizing BIM to improve VM during the construction phase can be grouped into three categories:

2.4.3.1 Effective Management

According to Sacks et al. (2018), project team may enhance coordination, monitor the status of procurements, and deal with any gaps or delays by integrating BIM with the construction schedule and using cloud-based procurement management solutions in VM practice. By utilizing BIM to enhance VM, the actual construction progress is compared with the planned progress during the monitoring process, which can keep the project on track by identifying potential delays early and taking corrective actions.

In addition, BIM provides tools for managing and analysing the performance of integrated building systems. This capacity assits to foresee and prevent conflicts between building systems and their performance throughout the construction process (Fadeyi, 2017). Design conflicts and errors can lead to costly rework and delays, undermining the project's value. By identifying potential clashes, clashes and coordination issues in VM implementation and resolving them, project teams can streamline the construction process and reduce costly rework.

Besides, managing project information across various documents and systems can lead to inconsistencies and inefficiencies in VM practice. The cloud services like ManufactOn offer a comprehensive platform for managing the entire procurement process, which includes streamlining procurement workflows, tracking material specifications, managing fabrication details, monitoring delivery schedules, and supervising installation activities (Sacks et al., 2018). This cloud-based approach increases transparency and improves coordination between all VM team parties involved in the procurement process.

2.4.3.2 Material Timeliness

Efficient resource management in terms of equipment and material usage helps save costs and enhance VM of projects. According to Fadeyi (2017), a BIM-based dynamic model for site material supply utilizes information from a BIM repository to optimize the procurement process, which considers various factors such as what materials are needed, how many should be procured, when they should be procured, and where they should be sourced from. Therefore, using BIM can address VM team inefficiencies by having the right materials on site at the right time, reducing waste and minimizing delays.

In addition, BIM considers factors such as workers' and equipment's actual movement paths on-site, spatial limitations, facility sizes, and internal storage within structures. Thus, it provides valuable insights for improving the layout and sizing of facilities on construction sites, ultimately improving project productivity and performance (Fadeyi, 2017).

Furthermore, Chatzimichailidou and Ma (2022) perceived that using BIM in modular construction has a lot more benefits than in traditional VM practice. The offsite modular construction involves fabrication or partially assembly in a manufacturing facility away from the construction site and then transport to the site for assembly. Therefore, utilizing BIM to design and plan prefab and modular construction processes can speed up construction, reduce labor costs, and improve quality control, enhancing the VM of projects.

2.4.3.3 Labour Effectiveness

BIM can significantly increase the labor efficiency of the VM process by reducing labour costs and improving overall project efficiency. The application of BIM is to identify and prevent potential safety issues that would enhance worker availability and safety at the construction site. This is because labour effectiveness will be increased if conditions for worker safety and motivation improve (Fadeyi et al., 2017).

According to Patel et al. (2023), BIM models provide more opportunities to contractors for off-site prefabrication and modular construction because of their precise and comprehensive representations of the project. Due to its smaller physical footprint on-site, modular construction provides the advantage of lowering manpower requirements and supplying a safer work environment (Chatzimichailidou and Ma, 2022). This can reduce labor costs because less labor is required to perform field work. In addition, factory environments offer better safety conditions than on-site construction sites because workers are in a controlled environment, so they are less exposed to adverse weather conditions, heavy machinery, and heights (Sacks et al., 2018).

Therefore, off-site prefabrication and modular construction are gaining popularity in construction industry as these methods can address the limitations of VM practices by improving worker safety, reducing the likelihood of accidents, and increasing labor productivity.

2.4.4 Post-Construction Stage

BIM can be used to enhance VM in the post-construction phase by maximising facility management, maintenance, and operations. During the post-construction stage, maintenance and facilities management operations are carried out to ensure the proper functioning of the structure and to extend its lifespan (Olanrewaju et al., 2022).

According to Stanley and Thurnell (2020) BIM serves as a reliable shared knowledge resource that allows the storage, access, and exchange of information and data related to a facility. Assessing and optimizing the lifecycle value of a project is difficult without comprehensive data on long-term performance and costs. Therefore, by analyzing the historical data in BIM related to operational and maintenance strategies, facility managers can make more informed decisions to optimize maintenance efforts and improve the facility performance. That is why BIM acts as a valuable knowledge resource to make informed value-enhancing choices that enhance VM in facility management throughout the project life cycle.

In addition, Stride et al. (2020) perceived that "As-built" BIM models eliminate the need for manual data entry into a Facility Management system by incorporating the manufacturer's information and specifications directly into the digital objects and components of the building. The information and specifications embedded within the "as-built" BIM models enable facility managers to streamline their facility management processes, carry out predictive and corrective maintenance, and enhance the efficiency of maintenance and operations (Fadeyi, 2017). However, it is necessary to regularly review and update the BIM model to reflect changes and improvements in the post-construction phase to ensure that the value of the facility is continuously optimized.

2.5 Advantages of Enhancing VM with BIM

Using BIM to enhance VM in the construction industry offers several advantages that improve project outcomes, increase efficiency, and maximize value. The advantages have been identified which will be further discussed in this section. Table 2.1 below summarises the advantages of enhancing VM with BIM from the literature review study.

2.5.1 Precise Cost Estimate and Control

Enhancing VM with BIM can significantly improve cost estimation and control throughout the project life cycle. According to Chan et al. (2019), BIM can generate detailed data for each building component, improving the accuracy of cost estimation and control. Therefore, VM uses this information to create more precise and reliable cost estimates based on actual project components.

Furthermore, Shaqour (2022) mentioned that BIM is employed for cost estimation and enhanced cost control by transforming conventional construction project drawings and documentation into object-oriented 3D models. These models are based on precise building information, facilitating more accurate project cost assessments. Besides, VM helps select cost-effective design options that meet project value objectives (Lin et al., 2023). Once any modifications are made to the design, stakeholders can evaluate how different design options affect cost, enabling them to make value-driven decisions that align with project goals and budget.

Additionally, clash detection in BIM helps reduce construction conflicts and saves money by avoiding costly rework (Yang and Chou, 2019; Cui et al., 2024). At the same time, VM emphasises waste reduction and cost savings through efficient project execution (Alsolami, 2022). By resolving clashes virtually before construction starts, project teams can communicate effectively between different project stakeholders to prevent delays and associated cost overruns due to coordination errors and change orders (Shaqour, 2022).

In addition, BIM can be utilized to conduct life cycle cost analysis (Haruna et al., 2021; Waqar et al., 2023). Therefore, BIM is able to represent the entire building lifecycle, enabling stakeholders to assess long-term costs. By incorporating data related to manufactured product information, maintenance manuals, operating costs and warranties, BIM can be used to evaluate maintenance costs and help define expenses for an asset during the course of a facility (Stride et al., 2020). This approach can improve VM by considering the full cost impact over time.

2.5.2 Enhance Collaboration and Communication

By enhancing VM with BIM, collaboration and communication among project stakeholders can be greatly improved throughout the project lifecycle.

BIM serves as a centralised digital model for efficient communication and collaboration by allowing the exchange and interoperability of information among the stakeholders (Othman et al., 2021; Nikologianni et al., 2022). Besides, this centralised repository ensures that all stakeholders have access to the latest data, reducing errors and miscommunication (Nikologianni et al., 2022). This up-to-date information supports timely communication of changes, progress and decisions related to value enhancement.

In addition, different design teams, contractors, and subcontractors may be in charge of various construction phases on a major infrastructure project (Celik et al., 2023). Wider stakeholder involvement in VM produces more effective value improvement approaches. As Nikologianni et al. (2022) mentioned that construction professionals can improve coordination, minimize errors and prevent delays caused by misunderstandings by utilising a digital platform that allows all project teams to collaboratively share and use a unified data set. Therefore, BIM can enhance VM practices to improve project information exchange and resolves numerous issues caused by miscommunication among stakeholders (Shaqour, 2022).

Moreover, BIM can be utilized to support facility management and operation (Yang and Chou, 2019; Raza et al., 2023). This is because BIM model can incorporate information about a facility, such as its construction, materials and maintenance schedules. This information can then be stored, retrieved and distributed via BIM as an accurate shared knowledge resource (Stride et al., 2020). Furthermore, VM is an invaluable tool for generating sustainable alternatives for the construction industry (Alsolami, 2022). Thus, this continuity of information ensures effective communication among VM teams to make cost-effective decisions that align with value objectives.

2.5.3 Accelerate Project Delivery Time

Enhancing VM with BIM can play a vital role in accelerating project delivery time while optimizing project value. According to Punnyasoma et al. (2019), BIM has attracted the attention of numerous projects all over the world because it is an efficient and time-saving technical solution.

BIM enables multidisciplinary teams to collaborate in a shared digital platform. As a result, BIM can quickly evaluate numerous design alternatives and schedules, manage change more easily, and improve assessment of a project's overall success (Olanrewaju et al., 2022). Likewise, VM emphasises collaborative decision-making to accelerate design iterations and minimize delay (Alsolami, 2022). Therefore, project teams can integrate VM from the beginning to identify key activities that affect project value and schedule. Using BIM to enhance VM in the early stages of a construction project can shorten the overall life cycle of the project (Chin et al., 2020).

In addition, BIM can automatically calculate quantities and generate accurate cost estimates based on digital models, resulting in saving significant time for manual calculations and estimates (Sacks et al., 2018; Tang and Liu, 2022; Raza et al., 2023). The time saved can be used for additional VM tasks like trade-off analysis and design change evaluation, leading to quicker decision-making and quicker project completion timelines.

2.5.4 Energy Efficiency and Sustainability

Utilizing BIM to enhance VM can significantly contribute to improved energy efficiency and sustainability in construction projects. Making wise design decisions at the beginning of construction projects is essential to achieving sustainability of the design structures (Haruna et al., 2021; Waqar et al., 2023).

According to Olawumi and Chan (2018), BIM provides 3D visualization capabilities allow project teams to evaluate different design alternatives and their impact on energy efficiency and sustainability. Besides, VM can assist in decision-making to select design alternatives that optimize energy performance and align with value objectives. Thus, BIM empowers VMto strike an optimal equilibrium between cost and functional performance, enabling stakeholders to attain value for their investment (Chin et al., 2020).

Additionally, BIM software can perform energy analysis and simulations using data embedded within the model (Durdyev et al., 2022). As Abanda and Byers (2016) stated that standardized and integrated data used to create BIM models can assist early building energy analysis, and the data generated from these simulations can be leveraged to quickly and efficiently develop more efficient design solutions. Thus, VM can use this information to make informed sustainable decision by considering sustainability benefits and costs over the project lifecycle (Lin et at, 2023).

2.5.5 Efficient Construction Planning and Management

Effective use of BIM to enhance VM can enable efficient construction planning and management. Celik et al. (2023) mentioned that BIM software is utilized to organize and visualize information related to the design, construction, and and administration of buildings, including 3D models, 2D drawings, and non-graphical data (metadata) of building components. Therefore, VM leverages these comprehensive visualizations for better planning and management, leading to more efficient construction process.

BIM facilitates the identification of constructability issues and potential clashes between various components to reduce delay (Othman et al., 2021, Raza et al., 2023). By leveraging BIM, VM can ensure that construction plans are aligned with value objectives by addressing constructability and time-overrun issues. Besides, early work planning through the use of BIM to improve VM gives the opportunity to solve issues through appropriate solutions and lowers the likelihood of running into issues like cost overruns and delays in the post-contract stage (Chin et al., 2020).

Furthermore, BIM-based processes can promote high-value sustainable design, including promoting sustainable material selection, reducing material usage, and employing more recycled resources (Punnyasoma et al., 2019, Waqar et al., 2023). As Olawumi and Chan (2018) stated that BIM can ensure materials efficiency while preventing and reducing material waste. Therefore, BIM can be used to assist VM teams in resource allocation optimisation to maximise project value and reduce waste, leading to effective project construction planning and management.

2.5.6 Improve Work Productivity and Quality

Enhancing VM with BIM to improve work productivity and quality involves leveraging BIM's capabilities to optimize workflows and enhance communication. BIM provides information exchange and interoperability among stakeholders throughout the project lifecycle by facilitating centralised data exchange, sharing and updating within a project (Othman et al., 2021; Nikologianni et al., 2022). This comprehensive data integration enables VM by enabling stakeholders to make informed decisions based on project objectives and prioritization of value drivers.

Besides, VM promotes team member participation and contribution and develops multidisciplinary teamwork (Chin et al., 2020). At the same time, BIM plays a major role in supporting real-time collaboration between multidisciplinary project teams (Celik et al., 2023). Therefore, enhancing VM through BIM enhances communication, facilitates knowledge exchange, and facilitates value-driven decision-making, thereby improving project productivity and quality throughout the project lifecycle.

In addition, BIM allows project teams to identify time-based clashes and eliminate potential clashes and conflicts between different building elements before construction starts (Akdag and Maqsood, 2019; Othman et al., 2021). Likewise, VM emphasises early detection of problems in projects and resolution and management of issues and conflicts (Lin et al., 2023). Thus, by analysing how various planning options impact project value, stakeholders can aid in the optimisation of project process.

2.5.7 Maintain the Construction Schedule

Applying BIM to enhance VM can maintain construction progress throughout the project. According to Shaqour (2022), BIM is utilised nowadays for project planning and scheduling purposes in construction because it provides an object-oriented 3D model including information that describe building in details. At the same time, VM can be used to optimize schedules, ensuring that key tasks are prioritized to increase project value (Lin et al. 2023). This combination helps project teams better understand the scope and complexity of the project, allowing for more accurate planning and scheduling and identify potential value-enhancing opportunities.

Furthermore, BIM aids in the planning of fabrication sequencing and coordination, materials order, and delivery schedule (Akdag and Maqsood, 2019). Alsolami (2022) also perceived that VM focus on minimizing waste and inefficiencies for a smooth construction schedule. Therefore, this allows project stakeholders to identify potential clashes or delays in the schedule and make adjustments to the plan to reduce delays. Early clashes detection reduces rework, keeps projects on track, and increases overall project value.

In addition, Othman et al. (2021) claimed that BIM can be used throughout the construction phase to monitor and track progress. Besides, VM emphasises risk control to ensure construction progress remains on track. Therefore, project team can identify potential deviations from the schedule and implement timely corrective actions to keep the project on track and within the defined value parameters.

2.5.8 Improve Decision-making

By enchancing VM with BIM, decision-making can be significantly improved throughout the project lifecycle. BIM is the digital representation of buildings, containing of vast amounts of data about various elements, such as materials, costs, and scheduling (Akdag and Maqsood, 2019; Raza et al., 2023). VM can use this data to assess the value impact of different design alternatives, construction methods, and material choices, leading to better-informed decisions.

According to Punnyasoma et al. (2019), BIM was found to be one of the most effective and precise tools for obtaining the fundamental and specific project data required for the VM process. At the same time, the objective of VM is to simultaneously optimise project functionality and cost (Lin et al., 2023). By analyzing the cost data and simulation provided by BIM, decision-makers can identify cost drivers and concentrate on items that provide the most value without compromising project performance or quality.

Furthermore, BIM can be used to analyze the environmental impact and energy performance of design decisions. For example, professionals can use BIM to virtually study how orientation affects a building's energy efficiency, allowing them to virtually make adjustments and make decisions among alternative options (Abanda and Byers, 2016). Besides, Lin et al. (2023) stated that VM has great potential in improving building design, construction, and operation in order to meet sustainability standards. VM considers the lasting value implications of decisions and facilitates choices that lead to lasting value over time. Therefore, BIM can help enhance VM to make informed value decision.

2.5.9 Increase Client Satisfaction

Enhancing VM with BIM in construction projects can significantly contribute to maximizing client satisfaction. Lin et al. (2023) claimed that the innovative ideas or alternatives resulting from the efforts of multidisciplinary VM teams are designed to enhance project functionality and value, and increase client satisfaction. At the same time, BIM provides a visual and interactive platform for presenting design concepts until project completion (Nikologianni et al., 2022). This enables clients to clearly understand of the design intent and value-added features of the project to meet their requirements and expectations.

Moreover, the visualization capabilities of BIM allow clients to preview their planned projects before construction actually starts (Olanrewaju et al., 2022, Raza et al., 2023). As a result, BIM can allow the design team the flexibility to change particular architectural features in response to feedback from clients. Besides, the application of BIM is to make effective decisions and assist in project management, thereby shortening the project duration and facilitating the efficient execution of cost management (Tang and Liu, 2022). Therefore, BIM can enhance the VM process by enabling stakeholders to investigate design options and evaluate their effects on value, time, cost, and other factors in order to make decisions that satisfy customer expectations.

2.5.10 Risk Identification and Mitigation

Enhancing VM with BIM can provide significant advantages in risk identification and mitigation by identifying potential risks, analyzing their impacts, and taking actions to mitigate them. According to Punnyasoma et al. (2019), BIM model provides a detailed and comprehensive representation of a project. As a generally accepted smart technology, BIM may have great potential to assist in VM in the early stages of project inception (Baarimah et al., 2021). By implementing BIM in VM practices, possible risks can be discovered early in the project, giving stakeholders time to rectify problems before they become more serious.

Furthermore, BIM facilitates the visual simulation of various project scenarios, enabling project participants to anticipate design errors and minimize the need for rework resulting from changes (Tang and Liu, 2022). By providing insights into the potential consequences of different design and construction options, construction simulation can help stakeholders gain a clearer understanding of associated risks, thereby increasing project value. Additionally, the collaborative aspect of BIM enables greater coordination among stakeholders, enabling them to take part in discussions about risk assessment and mitigation (Olanrewaju et al., 2022). Therefore, BIM can enhance VM practice by enhancing multidisciplinary engagement to find solutions to high-impact risks.

2.5.11 Facility Management and Operation

Enhancing VM with BIM can facilitate facility management and operations, realizing long-term value for construction projects. According to Durdyev et al. (2022), BIM provides a detailed and comprehensive digital representation of a facility, including not only its design and construction, but also its operations and maintenance aspects. This data becomes a crucial resource for facility management and operation, aiding in preventive maintenance, repairs, and the efficient operation of the building. As a result, construction projects can benefit from potential cost savings in maintenance and operations.

As Raza et al. (2023) stated that the 7D BIM model combines facilities management and operations, which is beneficial throughout the project lifecycle. The full lifespan of a construction project is supported by BIM, from planning and conception to constructing, overseeing, and maintaining the finished product. At the same time, VM emphasizes consideration of the entire lifecycle costs of a project (Lin et al., 2023). Therefore, this comprehensive approach ensures that decisions made align with the long-term value objectives of VM.

Additionally, the flexibility of BIM facilitates the continuous updating and modification of digital models (Schamne et al., 2024). This adaptability is particularly beneficial for facility management, enabling the accommodation of evolving building requirements, technological upgrades, and other factors over time. Therefore, the adaptability of BIM contributes to the longevity and sustained value of buildings in the face of changing demands and advancements in technology.

2.5.12 Lead to Better Choice and Optimize Project Outcome

Enhancing VM with BIM can substantially lead to better choices and optimize project outcomes. According to a study by Schamne et al. (2024), BIM leverages a shared, digital representation of a built asset to streamline the processes involved in design, construction, and operation, which facilitates informed decision-making throughout the project lifecycle. Therefore, when BIM is combined with VM principles, this ensures that the choices made are aligned with project objectives, maximizing value delivery.

Raza et al. (2023) mentioned that with 5D BIM models, project costs can be estimated quickly and accurately through automatic quantity take-offs of BIM models. The intelligent elements and incorporated data in the model help with accurate material and quantity calculations, which save time and reduce the possibility of human mistake. This quantification of resources and costs provides valuable data for VM analysis, enabling more informed decisions about resource allocation and cost-effectiveness.

In addition, the use of BIM guides material selection, emphasizing long-lasting choices. This approach not only reduces costs associated with maintenance and replacement but also mitigates adverse environmental impacts (Waqar et al., 2023). Therefore, selecting durable materials aligns with VM's goal of maximizing the value delivered by a project as this contributes to the longevity and performance of the structure, providing better value over the long term.

2.5.13 Avoid Costly Mistakes

Enhancing VM with BIM is a proactive measure to avoid costly mistakes in construction projects. Raza et al. (2023) claimed that BIM allows project stakeholders to visualize built deliverables before construction work even begins. With the visualization capabilities of BIM, stakeholders are able to understand design intent by visualizing the project in a complete 3D model. This visual representation helps identify potential issues or discrepancies before construction begins, preventing costly mistakes during the construction process, which is consistent with VM's approach to proactively managing risk and uncertainty.

Moreover, Cui et al. (2024) stated that construction companies employ clash detection techniques to identify and resolve potential conflicts efficiently, thereby minimizing rework and delays. BIM enables clash detection, which aids in identifying conflicts or inconsistencies in the design before construction begins. Besides, BIM facilitates better collaboration among project participants by providing a centralised information management platform for sharing information (Waqar et al., 2024). Improved collaboration and communication can help catch potential errors early in the process and avoid problems later. The clash detection and collaboration features of BIM are in line with the core principles of VM, which involve coordinating different aspects of a project to ensure efficiency.

Table 2.1: Summary of Advantages of Enhancing VM with BIM.

Advantages	Previous Studies																								
	Alsolami (2022)	Celik et al. (2023)	Chan et al. (2019)	Olanrewaju et al. (2022)	Punnyasoma et al. (2019)	Sacks et al. (2018)	Chin et al. (2020)	Nikologianni et al. (2022)	Othman et al. (2021)	Shaqour (2022)	Stride et al. (20220)	Yang and Chou (2019)	Haruna et al. (2021)	Lin et al. (2023)	Durdyev et al. (2022)	Olawumi and Chan (2018)	Abanda and Byers (2016)	Akdag and Maqsood (2019)	Baarimah et al. (2021)	Tang and Liu (2022)	Waqar et al. (2023)	Waqar et al. (2024)	Schamne et al. (2024)	Raza et al. (2023)	Cui et al. (2024)
Precise Cost Estimate and Control	✓		✓							✓	✓	✓	✓	✓							✓				✓
Enhance Collaboration and Communication	✓	✓						✓	✓	✓	✓	✓												✓	
Accelerate Project Delivery Time	✓			✓	✓	✓	✓													✓				✓	
Energy Efficiency and Sustainability							✓						✓	✓	✓	✓	✓				✓				

Table 2.1: Summary of Advantages of Enhancing VM with BIM (Continued).

	Previous Studies																								
Advantages	Alsolami (2022)	Celik et al. (2023)	Chan et al. (2019)	Olanrewaju et al. (2022)	Punnyasoma et al. (2019)	Sacks et al. (2018)	Chin et al. (2020)	Nikologianni et al. (2022)	Othman et al. (2021)	Shaqour (2022)	Stride et al. (20220)	Yang and Chou (2019)	Haruna et al. (2021)	Lin et al. (2023)	Durdyev et al. (2022)	Olawumi and Chan (2018)	Abanda and Byers (2016)	Akdag and Maqsood (2019)	Baarimah et al. (2021)	Tang and Liu (2022)	Waqar et al. (2023)	Waqar et al. (2024)	Schamne et al. (2024)	Raza et al. (2023)	Cui et al. (2024)
Efficient Construction Planning and Management		✓			✓		✓		✓							✓					✓			✓	
Improve Work Productivity and Quality Management		✓					✓	✓	✓					✓				✓							
Maintain the Construction Schedule	✓								✓	✓				✓				✓							
Improve Decision-making					✓									✓			✓	✓						✓	
Increase Client Satisfaction				✓				✓						✓						✓				✓	

Table 2.1: Summary of Advantages of Enhancing VM with BIM (Continued).

	Previous Studies																								
Advantages	Alsolami (2022)	Celik et al. (2023)	Chan et al. (2019)	Olanrewaju et al. (2022)	Punnyasoma et al. (2019)	Sacks et al. (2018)	Chin et al. (2020)	Nikologianni et al. (2022)	Othman et al. (2021)	Shaqour (2022)	Stride et al. (20220)	Yang and Chou (2019)	Haruna et al. (2021)	Lin et al. (2023)	Durdyev et al. (2022)	Olawumi and Chan (2018)	Abanda and Byers (2016)	Akdag and Maqsood (2019)	Baarimah et al. (2021)	Tang and Liu (2022)	Waqar et al. (2023)	Waqar et al. (2024)	Schamne et al. (2024)	Raza et al. (2023)	Cui et al. (2024)
Risk Identification and Mitigation				✓	✓														✓	✓					
Facility Management and Operation														✓	✓								✓	✓	
Lead to Better Choice and Optimize Project Outcome																					✓		✓	✓	
Avoid Costly Mistakes																						✓		✓	✓

2.6 Barriers of Enhancing VM with BIM

While BIM offers numerous benefits for enhancing VM in construction projects, there are a number of obstacles that can hinder its effective implementation. Some key barriers have been determined in this section. Table 2.2 below summarises the barriers of enhancing VM with BIM from the literature review study.

2.6.1 High Cost of Implementation

High implementation costs are a significant barrier organizations may face when attempting to enhance VM through BIM because the financial challenges can limit its widespread use across the industry. As Durdyev et al. (2022) mentioned that implementing BIM requires significant up-front cost, including the cost of purchasing BIM software and hardware and training of staff.

According to Akdag and Maqsood (2019), training and course education through lectures, seminars and workshops with BIM and VM professionals is required for implementing BIM to enhance VM. This is because a well-trained workforce can make better use of BIM to enhance VM, increasing efficiency and value. However, the initial education and training costs are too high for the construction industry to successfully adopt BIM to enhance VM (Ahmed, 2018). Thus, the training and education costs can be substantial if employees need training and education about the function of software and its methodology.

Besides, BIM tools such as Autodesk, Ecotect, Revit, Vasari, Ecotect, and Green Building Studio are necessary to implement the innovative VM proposal (Punnyasoma et al., 2019). Therefore, the purchase of BIM software will be included in the initial investment cost. However, the investment in software and hardware often outweighs training costs and initial lost productivity due to workflow change (Sacks et al., 2018). As Stanley and Thurnell (2020) claimed that upgrade of software and hardware is regarded as major obstacles to the adoption of BIM, especially for small and medium-sized enterprises (SMEs). The cost and complexity associated with upgrading software and hardware can present challenges in adopting BIM to enhance VM.

2.6.2 Industry Resistance to Process Change

Industry resistance to change from traditional work practices is a significant barrier when enhancing VM through BIM in construction projects (Olawumi and Chan, 2018).

Chen et al. (2022) stated that BIM adoption speeds up the business process by shifting conventional construction engineering projects from fragmented data and limited information integration to organized and comprehensive management. However, implementing BIM requires a significant shift in traditional workflows and practices, which can lead to resistance to change due to cultural barriers (Chan et al., 2019).

Furthermore, Tan and Ayalp (2022) mentioned that the transition from the industry's traditional 2D to 3D methodology is encountering objections from stakeholders. This is because traditional approaches have been used by all parties for a long time, they have been accustomed to them, and they are quite efficient while using them. As a result, stakeholders find it difficult to replace these methods, and not everyone finds them to be acceptable (Ahmed, 2018). In addition, certain stakeholders might be concerned that implementing BIM and altering present practises will interfere with ongoing projects, necessitate more training, or even jeopardise project outcomes. This can hinder the adoption of BIM to enhance VM as stakeholders resist to change.

2.6.3 Lack of Awareness and Understanding

Lack of awareness and understanding of BIM and VM is a significant barrier to utilizing BIM to enhance VM practices. As Othman et al. (2021) stated that the decision of top management to adopt BIM to enhance VM is significantly influenced by their awareness of its usage and its processing in construction projects.

According to Olanrewaju et al. (2022), client is not interested in engaging the BIM-developed project because of rising time and cost, and there is a lack of knowledge and skills as well as clarity regarding how BIM is used to enhance VM and how it relates to construction technology. This is because some project stakeholders may not fully understand the potential benefits of BIM for VM, leading to a lack of interest or motivation to adopt BIM to enhance VIM.

Furthermore, some AEC firms are reluctant to make large investments in technology, software or training related to BIM because they don't think they will get a quick return on their efforts (Takyi-Annan and Zhang, 2023). This is because certain organisations that aren't familiar with BIM could be resistant to change and doubt the potential worth of their project. Additionally, lack of confidence can hinder the enhancement VM with BIM, especially when they lack of knowledge or expertise to use BIM effectively (Ahmed, 2018). For example, stakeholders may have limited understanding of what BIM is and how it can be integrated with VM to increase project value.

2.6.4 Lack of Legal and Contractual Framework

Lack of contractual and legal framework identified as one of the key barriers to implement BIM to enhance VM of construction projects (Takyi-Annan and Zhang, 2023). As Olanrewaju et al. (2022) perceived that it is difficult to employ BIM to enhance VM of construction projects when contract procedures are not properly coordinated and planned to integrate these advanced technologies. Consequently, contractual and legal adjustments are necessary to enable the use of BIM to improve VM (Sacks et al., 2018).

For example, Stanley and Thurnell (2020) mentioned that the legal issues of who owns the information in BIM models, who is responsible for that information, what happens when the model has errors, and who is to be held liable for the problems have arisen and need to be addressed. Therefore, determining ownership and intellectual property rights associated with BIM models, data and information can lead to disputes among stakeholders. In addition, assigning responsibility for errors, omissions or discrepancies in BIM models and data can be complex, especially when multiple parties are involved.

In such cases, architects, alongside engineers and other professionals, may be liable for their designs under the traditional paper-based design method. However, determining such responsibility becomes challenging when using BIM (Olanrewaju et al., 2022). As a result, uncertainties and disputes arise regarding responsibilities, intellectual property, and liabilities can hinder the adoption of BIM to enhance VM.

2.6.5 Lack of Skill and Training

Lack of skills and training are significant barriers to successful adoption BIM to enhance VM. According to Takyi-Annan and Zhang (2023), lack of skilled professionals and expertise is a critical barrier to BIM implementation. This is because BIM implementation is infeasible in an environment lacking sufficient professionals equipped with the necessary knowledge and training (Olanrewaju et al., 2022). Team members may find it difficult to use BIM technologies efficiently without proper training, which could lead to underutilization and missed chances to improve VM.

Furthermore, Chan et al. (2019) claimed that the lack of qualified project personnel with BIM implementation experience hinders the widespread adoption of BIM to enhance VM. This is because the adoption of BIM to enhance VM is still a relatively new technology, so there is a shortage of skilled personnels who are familiar about its applications. As a result, lack of qualified personnel hinders the application of BIM to enhance VM because there is a lack of skilled personnel to promote and discuss its implementation (Olanrewaju et al., 2022).

In addition, there is lack of BIM and VM training in the academic and professional institutions in the developing world (Chen et al., 2022). Many academic institutions still do not fully include BIM and VM concepts into their course curricula. As a result, graduates might not have the knowledge and abilities when they enter the industry. This can lead to unfamiliarity with its workflows, which hinders the adoption of new technologies and processes, and hinders the adoption of BIM to enhance VM.

2.6.6 Lack of Interoperability and Data Exchange

According to Takyi-Annan and Zhang (2023), one of the main obstacles to enhancing VM with BIM is interoperability, a crucial technical issue that has significantly discouraged some professionals and clients from enhancing VM with BIM. They believe that the benefits of BIM for project delivery are overshadowed by this interoperability issue. The effectiveness of BIM to improve VM is called into question by a lack of interoperability, a weak adoption of BIM, and a lack of cooperation among project stakeholders (Gartoumi, 2023).

In addition, Olanrewaju et al. (2022) stated that the incompatibility of different BIM software hinders the application of BIM to enhance VM as different software packages cannot easily communicate with one another. Moreover, different BIM software tools may use proprietary file formats that do not easily interoperate with other tools, causing data exchange issues. Therefore, if these software tools do not communicate effectively and share data in a standardized manner, this hinders the collaborative work of project teams.

Furthermore, difficulties and data loss issues arise while transferring data from one software to another due to interoperability issues (Olawumi et al.,2018). Transferring data between software applications can sometimes result in data loss or corruption, which can affect the accuracy of the information. As a result, inefficient data transfers that result in information loss and disruption of VM operations happen when data is transferred across several platforms.

2.6.7 Arising of Data Privacy and Security Issues

Enhancing VM with BIM involves the utilization and sharing of digital project data, which can raise data privacy and security issues. According to Punnyasoma et al. (2019), BIM is an information solution that serves as a platform for storing the data required for a project while using BIM to enhance VM. Besides, BIM is used as a digital model to share data among practitioners (Stride et al., 2020). However, these digital assets are vulnerable to unauthorized access and hacking, which can lead to data breaches and disclosure of sensitive information. As a result, participants' confidence in the data privacy was significantly questioned (Othman et al., 2021).

Furthermore, Fadeyi (2017) stated that cloud-based storage and collaboration platforms are widely used in construction projects due to its high convenience. Data from several software-based databases may be connected and published online through a cloud-based BIM repository. All participants only need a username and password to access the cloud-based repository server throughout the project lifecycle. Nevertheless, these platforms may place project data at security risk due to the potential for data loss or unauthorised access. This will hinders the effective implementation of BIM to enhance VM.

2.6.8 Lack of Standardization

Lack of standardization is a significant barrier when enhancing VM with BIM. According to Chan et al. (2019), BIM standards, codes, and regulations are lacking, which makes it challenging to enhance VM using BIM.

Chan et al. (2019) claimed that the development of a national BIM industry standard is an important step in strengthening and development of BIM-enhanced VM. This is because a standardized framework provides a clear and consistent process for adopting BIM to enhance VM of construction projects (Stanley and Thurnell, 2020). Consequently, a lack of standardized processes hinders collaboration among multidisciplinary teams, leads to miscommunication and errors, and hinders the adoption of BIM to enhance VM.

Furthermore, companies in the AEC industry in developing countries have found it challenging to adopt BIM to improve VM due to the proliferation of non-standard BIM applications made by numerous software vendors because different countries have their own BIM standards and it is unclear which standards companies follow (Takyi-Annan and Zhang, 2023). Therefore, the lack of comprehensive industry standards and guidelines for BIM can create inconsistencies in BIM models and data, making it difficult to apply BIM effectively for VM.

Table 2.2: Summary of Barriers of Enhancing VM with BIM.

	Previous Studies																
Barriers	Akdag and Maqsood (2019)	Stanley and Thurnell (2020)	Chan et al. (2019)	Olanrewaju et al. (2022)	Punnyasoma et al. (2019)	Sacks et al. (2018)	Ahmed (2018)	Gartoumi (2023)	Tan and Ayalp (2022)	Chen et al. (2022)	Othman et al. (2021)	Takyi-Annan and Zhang (2023)	Sacks et al. (2018)	Stride et al. (2020)	Durdyev et al. (2022)	Olawumi and Chan (2018)	Fadeyi (2017)
High Cost of Implementation	✓	✓			✓	✓	✓	✓							✓		
Industry Resistance to Process Change			✓				✓	✓	✓	✓						✓	
Lack of Awareness and Understanding				✓			✓	✓			✓	✓					
Lack of Legal and Contractual Issue		✓		✓								✓	✓				

Table 2.2: Summary of Barriers of Enhancing VM with BIM (Continued).

Barriers	Previous Studies																
	Akdag and Maqsood (2019)	Stanley and Thurnell (2020)	Chan et al. (2019)	Olanrewaju et al. (2022)	Punnyasoma et al. (2019)	Sacks et al. (2018)	Ahmed (2018)	Gartoumi (2023)	Tan and Ayalp (2022)	Chen et al. (2022)	Othman et al. (2021)	Takyi-Annan and Zhang (2023)	Sacks et al. (2018)	Stride et al. (2020)	Durdyev et al. (2022)	Olawumi and Chan (2018)	Fadeyi (2017)
Lack of Skill and Training			✓	✓						✓		✓					
Lack of Interoperability and Data Exchange				✓				✓				✓				✓	
Arising of Data Privacy and Security Issues					✓						✓			✓			✓
Lack of Standardization		✓	✓									✓					

2.7 Strategies on disseminating the enhancement of VM with BIM

Disseminating the enhancement of VM with BIM involves a systematic approach to raising awareness, promoting understanding and encouraging adoption by the construction industry. The strategics have been identified and further discussed in this section. Table 2.3 below summarises the strategies on disseminating the enhancement of VM with BIM from the literature review study.

2.7.1 Conducting Conferences and Seminars

This lack of knowledge points to the need for seminars and workshops with professionals to foster interest in the adoption and implementation of BIM to enhance VM (Akdag and Maqsood, 2019). To disseminate the enhancement of VM with BIM, conferences and seminars serve as vital platforms for raising awareness and exchanging knowledge among construction professionals.

According to Chin et al. (2020), the conferences and workshops serve to spread practitioners' expertise and highlight the advantages of its application. By attending a conference or workshop related to the application, attendees can gain a deeper understanding of its benefits, challenges, and practical applications (Tan and Ayalp, 2022). Therefore, organisations should focus on promoting BIM through educational programmes, seminars, conferences, etc (Akdag and Maqsood, 2019). Any organisations who want to use BIM to enhance VM in their projects should be able to access this body of knowledge from these institutions.

Furthermore, (Othman et al., 2021) claimed that during the seminars, participants explored the project execution and the information flow through several organisations or stakeholders within the same project. Professionals can present practical techniques and case studies on using BIM to enhance VM during the seminars. Hence, seminar provides the opportunity to explore specific aspects of the adoption of BIM to enhance VM in more detail.

2.7.2 Legislation and Government Involvement

Legislation and government involvement is a strategic approach to disseminate the enhancement of VM with BIM. Government support can facilitate widespread adoption, standardization and incentivized integration of VM and

BIM practices across the construction industry. As Olanrewaju et al. (2022) stated that active government assistance is required to the increase the adoption of BIM to enhance VM. Besides, the successful adoption of BIM to enhance VM in the AEC industry depends on government's role in advocating for and implementing innovative technology (Chan et al., 2019).

Government BIM directives are closely linked to government policies, rules, and management systems since governments frequently release a directive with a strategic road map for updating and improving their rules, standards, and systems (Sacks et al., 2018). Beside, governments can work with industry stakeholders to develop comprehensive BIM standards, guidelines and protocols aligned with VM principles to encourage their adoption in projects.

Furthermore, Takyi-Annan and Zhang (2023) mentioned that establishing effective BIM and VM training and usage guidelines and standards for the construction industry in developing countries requires continuous multi-level collaboration between governments, AEC businesses, and educational institutions. To ensure consistency and interoperability among projects, governments should establish standardized BIM and VM guidelines and protocols that set the framework for data exchange, information modeling, and collaboration.

2.7.3 Establish a Start-up Funding Mechanism

Establishing a start-up funding mechanism is a strategic approach to disseminate the enhancement of VM with BIM. Chen et al. (2022) claimed that there is a lack of additional funds reserved to support BIM implementation. Therefore, creating a startup funding initiative can support organizations, projects, and professionals to adopt BIM to enhance VM practices.

According to Stride et al. (2020), lack of BIM expertise is an issues that requires a lot of time to overcome the learning curve experienced by untrained workers, and significant client expenditure in fund training. To address these issues, organizations should allocate funds for training and skill development programs that focus on VM integration within BIM environments. However, some AEC firms are reluctant to make significant investments in technology, software or training because they don't see a quick return on their investment (Takyi-Annan and Zhang, 2023). Hence, providing construction companies with start-up capital enables them to adopt BIM to enhance VM of their businesses and projects. This is because governmental financial backing can incentivize the implementation of BIM to enhance VM practices. By establishing a startup funding initiative for BIM implementation, it can encourage value-driven approaches and support the adoption of technologies that enhance project outcomes and overall VM (Chan et al., 2019).

2.7.4 Professional Training and Promotion Plan

Implementing a professional training and promotion plan can effectively disseminate the enhancement of VM with BIM. According to Olanrewaju et al. (2022), implementation of BIM is impossible in a situation that lack experts with the necessary skills and training. This is because, when there are no professionals to drive and execute the application of BIM to enhance VM, there is no discussion and criticism of its implementation.

Furthermore, attending trainings or workshops will improve participants' theoretical understanding of BIM and VM concepts (Othman et al., 2021). Professional training provides stakeholders with a solid foundation in BIM fundamentals, software usage, data management, and collaboration with VM. Besides, customized training programs are designed to meet the specific needs and roles of different team members, focusing on their responsibilities within the VM process. Therefore, the application of BIM to enhance VM requires continuous training to develop construction projects that satisfy clients and increase consumer confidence in the approach (Olanrewaju et al., 2022).

2.7.5 Inclusion of VM Clause and BIM in contract

The inclusion of VM clause and BIM requirements in contracts is a strategic approach to promote the enhancement of VM with BIM. By incorporating contractual agreements based on client needs, which is necessary to implement BIM-enhanced VM, it defines the unique requirements of VM and BIM integration as well as the roles and duties of each project stakeholder in this practise (Chen et al., 2022). This is because client needs expressed through contract documents can serve as a guiding framework for collaboration, enabling efficient information sharing and collaborative workflows for the successful implementation of BIM-enhanced VM.

In addition, according to Olanrewaju et al. (2022), in order to use BIM to enhance VM in a sufficiently cooperative project, the issue of personnel obstacles to contractual coordination must be resolved because it is difficult to implement for projects when contract procedures are not properly coordinated and planned. By listing the clauses related to VM and BIM in the contract, the level of detail and coordination requirements can be clarified to provide a clear framework for how stakeholders should collaborate using BIM-enhanced VM.

Furthermore, Sacks et al. (2018) perceived that when BIM and VM guidelines are legally empowered through their inclusion of construction contract clauses, they can strongly influence the behavior of project participants. This is because it encourages the use of BIM in a collaborative manner, which results in better project outcomes and improved VM across the project life cycle.

2.7.6 Roles of Educational Institutions

Educational institutions play a crucial role in disseminating the enhancement of VM with BIM because they equip students with the information and skills they need to effectively use BIM for enhanced VM in their future careers. As Yang and Chou (2019) perceived that universities with active education, training and research and development (R&D) activities are crucial to the successful implementation of BIM and VM with real and achievable benefits.

According to Takyi-Annan and Zhang (2023), higher education institutions must incorporate BIM and VM research into their curricula, and AEC firms should encourage employees to learn on the practise by rewarding employees who complete the training and requiring new hires to learn about the application of BIM to enhance VM. For example, incentives given to employees, such as bonuses or career development opportunities, can motivate employees to improve their BIM skills to enhance VM, resulting in a more knowledgeable and skilled workforce that can effectively contribute to projects.

Furthermore, if educational institutions place a strong emphasis on comprehensive BIM and VM training, the awareness will increase and more users would enter the market, thereby overcoming the reluctance of other companies to use BIM to enhance VM (Akdag and Maqsood, 2019). By giving faculty members access to chances for professional growth and training , they become more adept at providing students with in-depth knowledge and practical skills.

2.7.7 Standardization

Standardization is a key strategy for disseminating the enhancement of VM with BIM in the construction industry. According to Takyi-Annan and Zhang (2023), due to poor collaboration, communication and standardization, many problems and mistakes can occur during the construction phase. Interoperability standards are promoted and established to address these issues and improve VM integration by enabling data and information interchange between various BIM software platforms. This is due to the fact that standardisation minimises the risks of inconsistent project information and lowers the likelihood of errors.

In addition, the aim of buildingSMART International (bSI), a global organisation for standardisation, is to enhance exchange of data and workflow in the construction industry (Sacks et al., 2018). Standardized data formats and protocols facilitate data exchange between different BIM software applications and disciplines. This interoperability enables accurate information sharing and better coordination, contributing to enhance VM.

Furthermore, Chen et al. (2022) claimed that the Ministry of Housing and Urban–Rural Development has released The Application Standard of Building Information Model Construction and other policies to enhance the versatility of BIM. Government assistance and protocols are required in develop BIM standards to enhance Value Mangement (Takyi-Annan and Zhang, 2023). Therefore, governments play a major role in creating comprehensive BIM standards and guidelines that emcompass VM principles and practices.

Table 2.3: Summary of Strategies on disseminating the Enhancement of VM with BIM

Strategies	Previous Studies										
	Akdag and Maqsood (2019)	Chan et al. (2019)	Takyi-Annan and Zhang, (2023)	Chin et at. (2020)	Olanrewaju et al. (2022)	Sacks et al. (2018)	Stride et al. (2020)	Yang and Chou (2019)	Tan and Ayalp (2022)	Chen et al. (2022)	Othman et al. (2021)
Conducting Conferences and Seminars	✓	✓		✓					✓		✓
Legislation and Government Involvement		✓	✓		✓	✓					
Establish a Start-up Funding Mechanism		✓	✓				✓			✓	
Professional Training and Promotion Plan		✓			✓						✓
Inclusion of VM Clause and BIM in Contract					✓	✓				✓	
Roles of Educational Institutions	✓		✓					✓			
Standardization			✓			✓				✓	

2.8 Conceptual Framework

A conceptual framework is a key element in the research process, serving as an underlying structure that helps researchers organize and explain the relationships between different concepts or variables (Tsiulin et al., 2020). The conceptual framework of the study outlines of the interactions between the various variables and is shown in Figure 2.1. The variables of this study include the limitation of only using BIM or VM, the advantages and barriers of using BIM to enhance VM, and the strategies on disseminating the enhancement of VM with BIM.

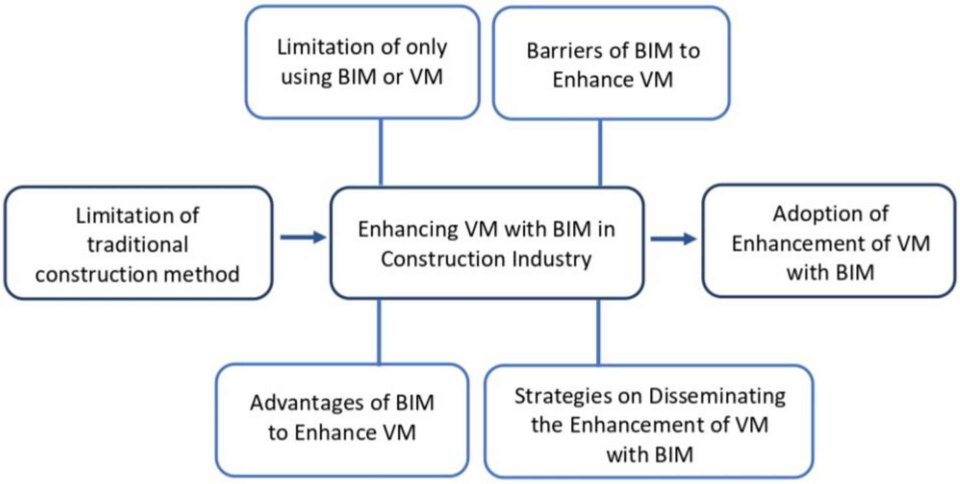

Figure 2.1: Conceptual Framework for the Adoption of Enhancement of VM with BIM

2.9 Summary

This chapter first explains the overview of VM and the definition of BIM. Next, the use of BIM to enhance VM during the project life cycle and its advantages are described. However, there are several challenges encountered in the Enhancement of VM with BIM. In order to overcome these issues, various strategies are suggested to disseminate the use of BIM to enhance VM.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter describes the research methodology and then explains the justification of selection of research philosophy and research method used to conduct this study. This chapter focuses on the quantitative research method, research design and sampling design. In the following, the sampling and data analysis methods applied in this study are described.

3.2 Definition of Research

Kothari (2004) defined research as a systematized effort to gain new knowledge. It involves a scientific and systematic investigation of relevant information on a particular topic. Research isn't just about gathering information, it's about solving unsolved problems or innovating to produce something that doesn't currently exist (Goddard and Melville, 2004). Since the purpose of research is to discover and create knowledge, it might be thought of as a process of broadening the scope of our ignorance. In addition, good research must be "systematic," that is well-planned, well-organized, and well-targeted. Kothari (2004) elaborated that research involves discovering truth through research, observation, comparison and experiment. Therefore, it is the methodical and objective search for knowledge to find answers to issues.

3.3 Research Philosphy

Research philosophy can be defined as a set of fundamental principles and essential concepts that guide the pursuit of knowledge enhancement (Saunders et al., 2016). In short, it outlines the process of advancing understanding and knowledge in a specific subject area of study, thereby helping researchers take into account the values and beliefs of the research being conducted. The following is the discussion of five main philosophical perspectives: positivism, critical realism, post modernism, pragmatism and interpretivism.

3.3.1 Positivism

Positivism is rooted in the philosophical approach of natural scientists, who examine observable social phenomena with the aim of generating generalizations (Alharahsheh and Pius, 2020). It emphasizes the significance of objective data and facts focusing strictly on considering pure information, free from the influence of human interpretation or bias. Positivism assumptions represent traditional research that prioritize quantitative approaches over qualitative ones (Creswell and Creswell, 2014).

3.3.2 Critical Realism

Critical realism, also known as direct realism, seeks to elucidate the world by exploring the fundamental structures of reality that govern observable phenomena (Saunders et al., 2016). It entails a detailed historical analysis of current configurations and dynamic organisations that cannot be fully represented by quantitative approaches and statistical data collection. Therefore, a variety of approaches and data formats are needed to effectively cover the topic.

3.3.3 Interpretivism

Interpretivism focuses on understanding the complex variables and contextual factors associated with a situation (Alharahsheh and Pius, 2020). It distinguishes humans from physical phenomena, recognizing that humans give meaning an extra layer of depth. Generally, interpretivism is regarded as a qualitative research approach (Creswell and Creswell, 2014). The researchers employ open-ended questions to enable respondents to express their perspectives and ideas.

3.3.4 Post Modernism

According to Saunders et al. (2016), post modernism delves into the nature of language and power dynamics. It questions an organization's concepts and beliefs, aiming to identify which perceptions and truths they overlook and whose interests they prioritize. In other words, post modernism involves examining existing discourse and uncovering hidden meanings (Ghauri and

Gronhaugh, 2010). This philosophy aims to challenge established ways of thinking and knowing by amplifying previously marginalized perspectives.

3.3.5 Pragmatism

Pragmatism prioritizes the investigation of research problems and questions, utilizing a variety of approaches to gain a comprehensive understanding of the issue (Creswell and Creswell, 2014). It emphasizes the importance of addressing the problems effectively by employing all available methodologies and promoting practical solutions (Saunders et al., 2016). Pragmatism focuses on practical, applied research, integrating diverse perspectives to solve problems and contribute to future practice.

3.4 Research Methods

According to Ghauri and Gronhaugh (2010), research methods involve the systematic, focused, and organized gathering of data with the aim of obtaining knowledge to address a specific research question or problem. The types of research methods commonly used in research include quantitative research, qualitative research, and a mixture of these two research methods, known as mixed research methods.

3.4.1 Quantitative Research Method

Quantitative research is a systematic approach based on the measurement of quantity or amount. In this research, data must be generated in a quantitative form that can be subjected to formal and rigorous quantitative analysis (Kothari, 2004). Quantitative research involves systematically analyzing observable phenomena through the application of statistical, mathematical, or computational methods (Bhawna and Gobind, 2015). This approach aims to draw objective insights and conclusion based on the numerical patterns and relationships in the data. For this approach, the methods for gathering data are typically semi-structured interviews and questionnaires (Ghauri and Gronhaug, 2010).

3.4.2 Quanlitative Research Method

Qualitative research has great significance in the field of behavioral sciences, aiming to reveal the fundamental drivers behind human behavior by conducting interviews. It involves subjective assessment of attitudes, opinions and behavior, and depends on the researchers' insights and impressions. (Kothari, 2004). Therefore, quanlitative data is not subjected to numerical analysis because it consists of narrative descriptions of observations or categorized data rather than numerical values (Crowtherm and Lancaster, 2012). However, this approach takes a long time to gather, process, and interpret data (Sreekumar, 2023).

3.4.3 Mixed Research Method

Mixed method research is characterised as a methodology that integrates both qualitative and quantitative techniques for gathering data and conducting analysis (Cooper and Schindler, 2014). Using multiple techniques can provide more accurate and insightful findings than using only one method. This is because it can provide stronger inferences for answering complex social phenomena and give opportunities to express different perspectives through different findings. Mixed methods can be helpful when neither quantitative research nor qualitative research can fully address a research question (Sreekumar, 2023). However, this strategy could be more time- and money-consuming because of the requirement of additional resources.

3.5 Justification of Selected Research Philosophy and Research Method

The pragmatic philosophy is a great fit for this study because of its emphasis on practical applications and problem solving (Saunders et al., 2016). As a result, the philosophy aligns well with the research objectives which explore the advantages and barriers associated with enhancing VM with BIM, as well as propose strategies for dissemination. Pragmatism allows for the integration of different perspectives and methodologies to accomplish the research aim which is to examine the enhancement of VM with BIM in the construction industry. In this study, it enables the investigation of practical implications and the development of strategies that can be applied to encourage the enhancement of VM with BIM.

Quantitative research is adopted for this study as it can provide reliable and quantifiable data. Closed-ended questions are answered by respondents, who are straightforward in their responses and produce numerical results that are consequently quite reliable. Besides, quantitative analysis involves collecting numerical data through questionnaire surveys. It employs statistical methods to organize, analyze, interpret and present these numerical data to precisely explore the relationship between dependent and independent variables (Sheard, 2018). Therefore, feedback and opinions from general respondents and past researchers can be obtained to identify the latest patterns and trends related to using BIM to enhance VM. Primary data was gathered through questionnaires, while secondary data was gathered through literature review. The data from literature review can be used to aid in the analysis of the outcomes of the quantitative results, leading to an in-depth knowledge of the research field.

The objective of this study is to determine the advantages, barriers and dissemination strategies for enhancing VM through BIM. Thus, a large number of questionnaires can be used to obtain the opinions and experiences of construction professionals to collect more research information. Quantitative techniques are useful for studying large populations and for generalizing from the sample under study to broader populations beyond that sample. In this research, a large number of participants was required to ensure the reliability of the results of respondents agreeing on the challenges and strategies for using BIM to improve VM. This approach could extend the findings to a wider population. Besides, this method is well-suited for the study because it can collect large amounts of data from large populations in a short period of time and in a cost-effective manner.

Furthermore, utilising statistical analysis software provides speedy and minimally labor-intensive analysis of massive volumes of data (Sreekumar, 2023). In this research, all the data collected related to the general background of respondents and the latest trend of the enhancement of VM with BIM will be analyzed and generated in the forms of tables, charts, and figures. Therefore, the rationale of adopting a quantitative approach lies in the ease and speed with which questionnaire results can be quantified, either by researchers or through computer software. In contrast, qualitative analysis is much more complex and time-consuming than quantitative analysis because qualitative data cannot be subjected to quantitative or numerical analysis. Consequently, the quantitative research method is more suitable to be adopted in this study because of its reliability, objectivity and generalizability.

3.6 Research Design

Research design is the process of organising the project's design following the task of defining the research problem (Kothari, 2004). It offers an investigation framework to help the researchers find answers to the issues. A research design provides an investigation framework that outlines a blueprint for how research will be conducted, guiding researchers in collecting, analyzing, and interpreting data to address research questions.

The study begins with choosing an appropriate field to study. Before proceeding with the selection of the research topic, the research scope 'information and communications technology (ICT)' is decided. Since there is too much to include in one report regarding ICT, it's advisable to incorporate related subjects to refine and concentrate the focus of the study. The topic of this research, "Enhancing VM with BIM in the construction industry," was chosen in view of the growing trend of using BIM and VM in this sector.

After identifying the topic, a comprehensive literature review is carried out by gathering data on existing theories and conducting research on the subject. To further investigate research objectives, relevant academic journals, articles, e-books, and webpages related to terms like "BIM" and "VM" are retrieved and examined. During the literature review process, the study areas that prior researchers had covered were analysed, and the research gap was discovered which was the adoption of using BIM to enhance VM. The issues identified helps to establish objectives and aim to solve problems or answer research gaps.

Next, quantitative research method is selected for this research to explore the advantages and barriers of using BIM to enhance VM, and the strategies on disseminating the enhancement of VM with BIM. Before distributing the questionnaire, identify the target respondents as construction professionals with expertise in VM or BIM. Following the completion of the questionnaire survey to gather data from the participants, the data is properly aggregated and data analysis is performed. Numerical data collected through quantitative research are ultimately summarized, described and analyzed using different data analysis methods in order to accomplish the goals of the research. For instance, the backgrounds of respondents, their level of agreement with the adoption of enhancing VM with BIM and the challenges faced are summarized in tables, charts, and figures.

Lastly, a comprehensive conclusion is developed by discussing the significance of the findings and relating them to previous theory and study. The research design workflow applied in the study is shown in Figure 3.1.

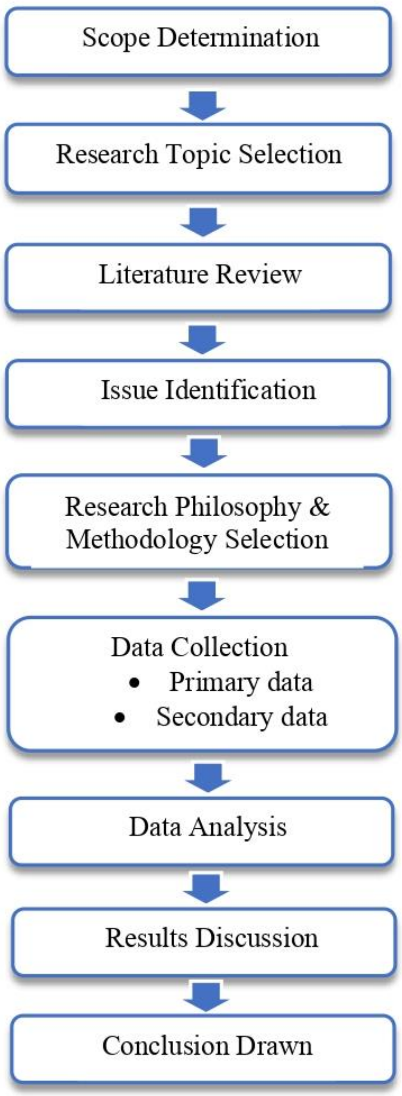

Figure 3.1 : Research Design Workflow

3.7 Research Instrument

A research instrument is a tool or technique used to gather data for research endeavors, encompassing a range of methods like surveys, questionnaires, interviews, observations, experiments, or tests. The data collection procedures for the study are explained below.

3.6.1 Questionnaire Design

The target respondents for this study were surveyed using a questionnaire to gather data. Table 3.1 displays the division of the questionnaire into four sections. The interviewee's demographic information is examined in the first section, Section A. This information includes nature of the company's business, the respondent's position within the organization, their professional background, their work experience, and the size of the company. These collected information functions as independent variables used to examine their relationships with the dependent variables outlined in Sections B, C, and D of the questionnaire.

Additionally, Section B focused on the usage of enhancing VM with BIM in the construction projects. Section C and D are then further divided into two subsections. One of the subsections in Section C explored the extent to which respondents agree with the advantages of enhancing VM with BIM. Another subsection of this section examined the advantages incurred in construction projects by using BIM to enhance VM. There are 13 assertions are mentioned in both subsections in Section C.

The first subsection of Section D covered the barriers of enhancing VM with BIM that the respondents encountered in ongoing or past projects. The second subsection of Section D examined the effectiveness of the strategies to encourage the enhancement of VM with BIM in construction projects. In the questions under Section B, C, and D, the participants were required to rate their opinions on a five-point Likert scale from 1 to 5. To show the degree of agreement with the numerous criteria investigated in the study, a rating of 1 indicates the least importance and a rating of 5 indicates the greatest importance.

Table 3.1: Summary of Questionnaire Design

Section	Description
A	Demographic Information
B	The Usage of Enhancing VM with BIM
C	Advantages of Enhancing VM with BIM
D	Barriers and Strategies of Enhancing VM with BIM

3.8 Sampling

According to Kothari (2004), sampling involves choosing a portion of a larger whole or entity upon which assessments or conclusions about the entire entity are based. It is a critical process that involves studying a subset of a population to gather insights that reflect the characteristics of the entire population. To increase the credibility of research findings, a sufficient sample of appropriate participants must be carefully identified and selected from the target population. The population, sample frame, sample design, sample size, and execution of the sampling process will be determined during sampling design.

3.8.1 Defining the Population

A population is the totality of individuals or objects (the unit of analysis) possessing the attributes one intends to investigate. This unit of analysis can encompass individuals, groups, organizations, nations, tangible items, or any other entity from which scientific conclusions are sought (Bhattacherjee, 2012). The targeted population for this study consists of the practitioners from different business organisations, professions, positions, company sizes and work experiences who are currently active in the Malaysian construction industry and have expertise in using BIM or VM. These individuals are considered the most suitable candidates to respond to inquiries and offer perspectives relevant to the research investigation.

3.8.2 Determining the Sample Frame

A sampling frame refers to a foundational component of the sampling process in research. It is essentially a list or database containing all the elements (individuals, units, or entities) that make up the population under study. This list serves as the source from which the researcher selects the sample to be included in the study (Cooper and Schindler, 2014).

In this study, the sampling frame consists of four distinct categories, namely consultants, contractors, developers, and others. To ensure the reliability and validity of the sampled data, the study emphasizes the importance of obtaining accurate information regarding the legal registration and certification status of the construction companies within these categories. These information can be easily obtained from relevant authorities and governmental bodies such as the Construction Industry Development Board (CIDB), Pusat Khidmat Kontraktor (PKK), Board of Quantity Surveyors Malaysia (BQSM), and Suruhanjaya Syarikat Malaysia (SSM).

3.8.3 Determining the Sample Design

Sampling design is divided into probability sampling and non-probability sampling. Probability sampling ensures that each unit in the population has a known non-zero probability of being selected for the sample, and this likelihood can be precisely determined (Bhattacherjee, 2012). This method involves random selection at some stage of the sampling procedure. In constrast, non-probability sampling is a method of sampling where certain units within the population either have no chance of being selected or where it's not possible to accurately calculate their probability of selection.

In this study, the expert sampling was utilised as the sampling method to select the respondents. This method falls under the category of non-probability sampling techniques. Expert sampling is utilized when research demands individuals with advanced knowledge in a particular field (Nikolopoulou, 2022). This approach is advantageous in scenarios where new research areas are explored. Regarding the topic of Enhancing VM with BIM, expert sampling required the selection of individuals with extensive expertise or experience in VM or BIM. Their insights will greatly contribute to the development of knowledge and strategies in this area.

3.8.4 Determining the Sample Size

Sample size refers to the quantity of observations or individuals incorporated into a study or experiment (Coursera, 2023). The sample size in this study is decided using the Central Limit Theorem (CLT). Ganti (2024) explains that according to the CLT, an increasing sample size causes a sample variable's distribution to converge towards a normal distribution, often described as a "bell curve." Typically, a sample size between 30 and 50 is considered sufficient for the CLT to apply effectively. This implies that the distribution of sample means tends to exhibit a reasonably normal distribution. As more samples are collected, the distribution of these sample means increasingly resembles a bell curve shape associated with a normal distribution.

Therefore, to guarantee the validity of the study's results, at least 30 responses would be collected for each demographic variable. Consequently, it was anticipated that a minimum of 120 samples would be required, taking into account the four different categories of respondents' attributes, including consultants, contractors, developers and others. This strategy aims to generate a reliable dataset that adequately represents various demographic factors, thus enhancing the credibility and validity of the study's conclusions.

3.8.5 Executing the Sampling Process

The subsequent step involved the commencement of the data collection phase (Gimino, 2023). A questionnaire crafted using Google Forms was distributed using popular social media platforms such as LinkedIn, email and WhatsApp. This questionnaire specifically targeted construction practitioners across Malaysia, aiming to explore their perspectives and attitudes concerning the adoption of BIM to enhance VM practices within construction projects. Through this approach, we collectively gather the diverse insights and experiences of industry professionals. Next, the collected data will be thoroughly analyzed using a series of impactful tests outlined in the subsequent section of the research methodology.

3.9 Data Analysis

This section outlines the data analysis methods employed in the study. There are various statistical tests will be applied for the study, including Cronbach's alpha reliability test, Friedman test, Kruskal-Wallis H test and Spearman rank-order correlation test.

3.9.1 Cronbach's Alpha Reliability Test

Cronbach's alpha evaluates the reliability of a measurement tool by examining the extent of shared variance among its items relative to the total variance (Collins, 2007). It quantifies the level of agreement on a scale from 0 to 1 (Frost, 2024). Cronbach's alpha is typically considered satisfactory if it reaches 0.7 or higher. The questions were sufficiently consistent at this level and above, indicating the reliability of the measure. Table 3.2 shows the general guidelines for the alpha value. The purpose of this test was to assess the internal reliability of the Likert scale items within Sections B, C, and D of the questionnaire regarding the usage of enhancing VM with BIM, the advantages of enhancing VM with BIM and the barriers and strategies for the enhancement VM with BIM.

Table 3.2: General guidelines for Cronbach's alpha value (Arof et al., 2018)

Cronbach's Alpha	Internal consistency
$\alpha \geqslant 0.90$	Excellent
$0.89 \geqslant \alpha \geqslant 0.8$	Good
$0.79 \geqslant \alpha \geqslant 0.7$	Acceptable
$0.69 \geqslant \alpha \geqslant 0.6$	Questionable

3.9.2 Friedman test

According to Laerd Statistics (2018), when the dependent variable is ordinal, the Friedman test, which is the nonparametric equivalent of a one-way ANOVA with repeated measures are intended to assess group differences. The test essentially determines if the differences between groups that have been detected are statistically significant by evaluating the relative rankings of those groups. The test was employed in sections B, C, and D of the questionnaire to assess the importance level of the dependent variables concerning the usage and advantages of enhancing VM with BIM, and the obstacles and strategies related to enhancing VM with BIM.

3.9.3 Kruskal-Wallis H Test

The Kruskal-Wallis H test, also referred to the "one-way ANOVA on ranks," is a nonparametric test based on ranks (Laerd Statistics, 2018). It evaluates whether there are noteworthy variations in an independent variable between two or more groups with respect to an ordinal or continuous dependent variable. The p-value that was computed indicates a significance level of 0.05 (Datatab, 2024). The null hypothesis is disregarded if the p-value is less than this threshold, but it remains in place if it is greater.

The Kruskal-Wallis H test was used in this study to examine whether there were any noteworthy variations in opinions across the various participant groups concerning their companies business activities, professions, positions, working experience and company size. Additionally, the rejection of the null hypothesis for each of the variables in Section B and D1, which represent the the usage and barriers of enhancing VM with BIM, is another goal of this test.

3.9.4 Spearman's Rank-Order Correlation

The Spearman rank-order correlation coefficient assesses the direction and degree of connection between two variables that are both evaluated on an ordinal scale using a nonparametric method (Laerd Statistics, 2018). The coefficient value ranges from -1 to 1, where 1 and -1 represent the strongest positive and negative correlations, respectively (Nagwa, 2024). It indicates that a rank correlation coefficient of 1 or -1 indicates perfect agreement (r=1) or direct opposite (r=-1) between the ranks respectively. Therefore, this test is applied to assess the correlation between Sections D1 and D2 of the questionnaire, which are respectively the barriers that hinder the use of BIM to enhance VM and the strategies to encourage the use of BIM to enhance VM. This is to examine and determine the effectiveness of the proposed strategy in addressing the particular barrier. Table 3.3 displays the Spearman correlation coefficient (ρ) as a grading system.

Table 3.3 : Grading of Spearman Correlation Coefficient (ρ) (Leclezio et al., 2015)

Spearman, ρ	Strength of Association
$\rho \geqslant 0.70$	Very strong
$0.69 \geqslant \rho \geqslant 0.4$	Strong
$0.39 \geqslant \rho \geqslant 0.3$	Moderate
$0.29 \geqslant \rho \geqslant 0.2$	Weak
$0.19 \geqslant \rho \geqslant 0.01$	No or negligible

3.10 Summary

The research philosophy and methodology used in the research has been discussed in this chapter. This section covered the pragmatism philopsphy and quantitative method used in this study, which included questionnaire surveys. This streamlines the entire data collection procedure that was carried out. The research design workflow is presented. Expert sampling was used as the sampling method to select respondents with expertise in BIM or VM practices. Furthermore, the selected data analysis methods were used to examine all of the data gathered from the respondents.

CHAPTER 4

DATA ANALYSIS

4.1 Introduction

The chapter starts with an overview of the demographic background of the 132 respondents who participated in the questionnaire survey. Subsequently, the collected data were then organized and analyzed using the methods described in Chapter 3 using SPSS software. The purpose of the analysis and discussion in this chapter is to achieve the aims and specific objectives identified in Chapter 1.

4.2 Demographic Information of Respondents

Since February 16, 2024, a total of 300 invitations to respond to the comprehensive questionnairewere sent out to target respondents through various channels including LinkedIn, email and WhatsApp. As of March 23, 2024, a total of 132 valid responses have been received, with a response rate of 44%. Table 4.1 summarised the demographic information of the respondents.

According to Table 4.1, the study mainly involved the practitioners working in consulting firms (30.3%), followed by contracting business (23.5%), other types of business nature, namely subcontractors, suppliers and specialists (23.5%) and property development (22.7%). Quantity surveyors accounted for more than one-third of the respondents (34.80%), which is relatively higher than Civil & Structural (C&S) Engineer / Mechanical & Electrical (M&E) Engineer (28.10%), Architect (22.70%) and Builder (14.40%). Among the participants, the vast majority are senior executives and junior executives, accounting for 42.40% and 33.30%, respectively. More than two-thirds of respondents (69.70%) possess over two years of work experience, which reflects the reliability and depth of respondents’ responses. Additionally, the respondents mainly come from three types of companies of different sizes, with 0-30 people (41.90%), 31-75 people (32.10%) and more than 75 people (26.00%).

Table 4.1 : Demographic Information of the Respondents.

Demographic Information	**Categories**	**Frequency (n)**	**Percentage (%)**
Company business nature	Consulting	40	30.30
	Contracting business	31	23.50
	Property Development	30	22.70
	Other	31	23.50
Profession	Quantity Surveyor	46	34.80
	Architect	30	22.70
	C&S Engineer / M&E Engineer	37	28.10
	Builder	19	14.40
Position	CEO/ Director/ Contract Manager/ Head of Department	32	24.30
	Team Leader/ Senior Executive	56	42.40
	Junior Executive/ Fresh Graduate	44	33.30
Working Experience	0 - 2 years	40	30.30
	3 – 5 years	17	12.90
	6 – 10 years	36	27.30
	11 – 20 years	23	17.40
	21 years and above	16	12.10
Company Size	0 – 30 people	55	41.90
	31 – 75 people	42	32.10
	More than 75 people	34	26.00

4.3 Cronbach's Alpha Reliability Test

Table 4.2 presents the results of the Cronbach's Alpha Reliability Test performed in sections B, C, and D of the questionnaire. Generally, a Cronbach's alpha of 0.7 or above is considered acceptable. Larger values indicate stronger correlations between items in the scale. Therefore, the results of 0.900, 0.912, and 0.834 indicate high levels of consistency among the items on the scale.

Table 4.2 : Cronbach's Alpha Reliability Test

Section Number of Items	**Number of Items**	**Cronbach's Alpha**
B	13	0.900
C	26	0.912
D	15	0.834

4.4 Agreement on the Advantages of Enhancing VM with BIM

Table 4.3 displays the mean ranking of the target participants for the Agreement on the advantages of Enhancing VM with BIM in the Construction Industry. The top three agreements ranked by the participants were BE9 – The enhancement of VM with BIM leads to better choices and optimizes project outcomes, BE2 – The enhancement of VM with BIM improves collaboration and communication among project stakeholders, and BE5 –The enhancement of VM with BIM improves work productivity and quality. However, the rankings respondents gave the least agreement were BE13 – The enhancement of VM with BIM helps facility management and operation, realizing long-term value for the built environment and BE12 – The enhancement of VM with BIM increases client satisfaction".

Table 4.3 : Mean ranking of Respondents' Agreement on the Advantages of Enhancing VM with BIM

Code	**Statement**	**Mean Rank**	**Chi-square**	**Asymp. Sig.**
BE9	The enhancement of VM with BIM leads to better choices and optimizes project outcomes.	8.70	240.306	<.001
BE2	The enhancement of VM with BIM improves collaboration and communication among project stakeholders.	8.61		
BE5	The enhancement of VM with BIM improves work productivity and quality.	8.41		
BE3	The enhancement of VM with BIM enables precise cost estimation and control.	8.21		
BE6	The enhancement of VM with BIM enables efficient construction planning and management.	8.05		
BE4	The enhancement of VM with BIM contributes to energy efficiency and sustainability.	7.22		
BE8	The enhancement of VM with BIM improves the decision-making process for construction projects.	6.69		
BE1	The enhancement of VM with BIM accelerates project delivery time.	6.34		
BE10	The enhancement of VM with BIM aids in identifying and mitigating risks in construction projects.	6.24		
BE11	The enhancement of VM with BIM helps avoid costly mistakes.	6.05		
BE7	The enhancement of VM with BIM contributes to maintain the construction schedule.	5.93		
BE13	The enhancement of VM with BIM helps facility management and operation, realizing long-term value for the built environment.	5.42		
BE12	The enhancement of VM with BIM increases client satisfaction.	5.14		

Table 4.4 delineates the mean ranking of the respondents' level of agreement on the Advantages in Ongoing/past Construction Projects by Enhancing VM with BIM. Based on the findings, the majority of respondents concurred that enhancing VM with BIM results in enhanced decision-making and optimization of project outcomes in their projects. Additionally, they indicated that this integration improves work productivity and project quality. Moreover, respondents agreed that VM enhanced with BIM improves better collaboration and communication among project stakeholders. Despite this, the respondents expressed the least agreement on the effectiveness of the enhancement of VM with BIM in helping avoid costly mistakes and increasing client satisfaction in their projects.

Table 4.4: Mean ranking of Respondents' Agreement on the Advantages incurred in the Ongoing/past Construction Project by using BIM to Enhance VM

Code	Statement	Mean Rank	Chi-square	Asymp. Sig.
BP9	The enhancement of VM with BIM leads to better choices and optimizes project outcomes in my projects.	8.87	276.114	<.001
BP5	The enhancement of VM with BIM improves work productivity and the quality of my projects.	8.44		
BP2	The enhancement of VM with BIM improves collaboration and communication among project stakeholders in my projects.	8.39		
BP3	The enhancement of VM with BIM enables cost estimation and control in my projects.	8.23		
BP6	The enhancement of VM with BIM enables efficient construction planning and management in my projects.	8.11		
BP4	The enhancement of VM with BIM improves the energy efficiency and sustainability of my projects.	7.38		
BP8	The enhancement of VM with BIM improves the decision-making process in my projects.	6.84		
BP10	The enhancement of VM with BIM aids in identifying and mitigating risks in my projects.	6.56		
BP1	The enhancement of VM with BIM accelerates delivery time in my projects.	6.44		
BP7	The enhancement of VM with BIM contributes to maintaining the construction schedule in my projects.	5.77		
BP13	The enhancement of VM with BIM helps facility management and operation, realizing long-term value in my projects.	5.51		
BP11	The enhancement of VM with BIM helps avoid costly mistakes in my projects.	5.44		
BP12	The enhancement of VM with BIM increases client satisfaction in my projects.	5.03		

4.5 The Usage of Enhancing VM with BIM

Table 4.5 shows the mean ranking of target respondents regarding the usage of enhancing VM with BIM. The top three usages are SS7 – "The BIM model in my project is used to create visualizations that help clients better understand the project", SS5 – "We conduct cost-benefit analysis of the construction project during the VM/VE process", and SS1 – "My company practises post project review whenever the construction project is completed". On the other hand, the two usages with the lowest adoption rates are SS3-"My company conducts VM/VE workshops to encourage creative thinking and idea generation", and SS11-"We use BIM software during the VM/VE process".

Table 4.5 : Mean Ranking of the Usage of Enhancing VM with BIM

Code	Statement	Mean Rank	Chi-square	Asymp. Sig.
SS7	The BIM model in my project is used to create visualizations that help clients better understand the project.	9.16	351.470	<.001
SS5	We conduct cost-benefit analysis of the construction project during the VM/VE process.	9.14		
SS1	My company practises post project review whenever the construction project is completed.	8.50		
SS6	My company practises BIM in the construction project.	8.24		
SS9	We use BIM software to enhance communication and coordination among project stakeholders.	7.84		
SS2	My company practises VM/ VE in the construction project.	7.76		
SS4	We identify and prioritize the key values and objectives for the construction project during the VM/VE process.	7.21		
SS12	We advocate to use BIM in the VM/VE study.	6.45		
SS8	We use BIM tools to monitor the entire building lifecycle.	6.05		
SS10	We use available standards (eg: ISO 19650, BIM protocol, etc.) to support BIM management.	5.79		
SS13	We make BIM as mandatory for the VM/VE study.	5.13		
SS3	My company conducts VM/VE workshops to encourage creative thinking and idea generation.	4.95		
SS11	We use BIM software during the VM/VE process.	4.79		

The Kruskal-Wallis test was conducted to assess variations in agreement levels among respondents concerning the usage of VM enhancement with BIM based on their demographic details. Table 4.6 illustrates the null hypothesis rejection for the usage of VM enhancement with BIM regarding respondents' demographic information, highlighting statistically significant findings with $p < 0.05$.

Table 4.6 : Rejected Null Hypothesis for the Usage of VM Enhancement with BIM and the Respondents' Demographic Information

Code	Null Hypothesis	Asymp. Sig.
	Business Activity	
SS6	My company practises BIM in the construction project.	0.009
SS9	We use BIM software to enhance communication and coordination among project stakeholders	0.003
SS11	We use BIM software during the VM/VE process.	0.019
	Profession	
SS6	My company practises BIM in the construction project.	<.001
SS8	We use BIM tools to monitor the entire building.	<.001
SS11	We use BIM software during the VM/VE process.	<.001
	Working Experience	
SS1	My company practises post project review whenever the construction project is completed.	0.016
SS4	We identify and prioritize the key values and objectives for the construction project during the VM/VE process.	0.026
SS13	We make BIM as mandatory for the VM/VE study.	0.031
	Position	
SS1	My company practises post project review whenever the construction project is completed.	0.040

The findings of the Kruskal Wallis test for the usage of VM enhancement with BIM are shown in Table 4.6 and summarized as follows:

(A) The group of Consultant agreed

(i) more towards SS6 – "My company practises BIM in the construction project." (mean rank = 78.36) than group of Developer (mean rank = 73.78), Contractor (mean rank = 55.90) and Other (mean rank = 54.74)

(ii) more towards SS9 – "We use BIM software to enhance communication and coordination among project stakeholders." (mean rank = 79.90) than group of Developer (mean rank = 72.03), Other (mean rank = 61.63)), and Contractor (mean rank = 48.73) .

(iii) more towards SS11 – "We use BIM software during the VM/VE process." (mean rank = 77.96) than group of Contractor (mean rank = 71.19), Other (mean rank = 60.39), and Developer (mean rank = 52.68) .

(B) The group of Architect agreed

(i) more towards SS6 – "My company practises BIM in the construction project." (mean rank = 85.47) than group of Quantity Surveyor (mean rank = 74.65), C&S Engineer /M&E Engineer (mean rank = 56.11) and Builder (mean rank = 36.00)

(ii) more towards SS8 – "We use BIM tools to monitor the entire building lifecycle." (mean rank = 77.02) than group of Quantity Surveyor (mean rank = 76.87), C&S Engineer /M&E Engineer (mean rank = 60.88) and Builder(mean rank = 34.33)

(iii) more towards SS11 – "We use BIM software during the VM/VE process." (mean rank = 80.28) than group of Quantity Surveyor (mean rank = 77.77), C&S Engineer /M&E Engineer (mean rank = 55.46) and Builder (mean rank = 38.03)

(C) The group of > 21 years working experience perceived

(i) more towards SS1 – "My company practises post project review whenever the construction project is completed." (mean rank = 90.38) than group of 3-5 years (mean rank = 71.03), 11-20 years (mean rank = 67.72), 6-10 years (mean rank = 62.25), and 0-2 years (mean rank = 58.15).

(D) The group of 6-10 years working experience perceived

(i) more towards SS4 – "We identify and prioritize the key values and objectives for the construction project during the VM/VE process." (mean rank = 74.92) than group of 11-20 years (mean rank = 74.33), 0-2 years (mean rank = 65.56), > 21 years (mean rank = 62.75) and 3-5 years (mean rank = 43.82).

(E) The group of 11-20 years working experience perceived

(i) more towards SS13 – “We make BIM as mandatory for the VM/VE study.” (mean rank = 79.59) than group of 3-5 years (mean rank = 74.65), 0-2 years (mean rank = 67.95), 6-10 years (mean rank = 62.49) and > 21 years (mean rank = 44.44).

(F) The group of CEO/ Director/ Contract Manager/ Head of Department perceived

(i) more towards SS1 – “My company practises post project review whenever the construction project is completed.” (mean rank = 77.47) than group of Assistant Manager/ Team Leader/ Senior Executive (mean rank = 66.71) and Junior Executive/ Fresh Graduate (mean rank = 58.25).

4.6 Barriers of Enhancing VM with BIM

Table 4.7 presents the target respondents' mean ranking of the barrier that undermine the enhancement of VM with BIM in construction project. The top three barriers were BR1 - High Cost of Implementation, followed by BR2 - Industry Resistance to Process Change and BR5 - Lack of Skill and Training. On the contrary, the last two barriers were BR7 - Data Privacy and Security Issues and BR6 - Lack of Interoperability and Data Exchange.

Table 4.7 : Mean Ranking of the Barriers that undermine the enhancement of VM with BIM

Code	**Statement**	**Mean Rank**	**Chi-square**	**Asymp. Sig.**
BR1	High Cost of Implementation	5.87	222.019	<.001
BR2	Industry Resistance to Process Change	5.53		
BR5	Lack of Skill and Training	5.28		
BR3	Lack of Awareness and Understanding	4.80		
BR4	Lack of Legal and Contractual Framework	3.98		
BR8	Lack of Standardization	3.96		
BR7	Data Privacy and Security Issues	3.30		
BR6	Lack of Interoperability and Data Exchange	3.28		

The Kruskal-Wallis test was utilized to investigate potential variations in respondents' perceptions of the barriers hindering the enhancement of VM with BIM, taking into account their demographic attributes. Table 4.8 shows the null hypothesis rejections for the barriers associated with using BIM to enhance VM across respondents' demographic details, identifying statistically significant results with $p < 0.05$.

Table 4.8 : Rejected Null Hypothesis for Barriers that undermine the enhancement of VM with BIM and the Respondents' Demographic Information

Code	Null Hypothesis	Asymp. Sig.
	Business Activity	
BR1	High Cost of Implementation	0.014
BR3	Lack of Awareness and Understanding	0.027
BR5	Lack of Skill and Training	0.045
	Profession	
BR1	High Cost of Implementation	0.021
BR2	Industry Resistance to Process Change	0.034
BR6	Lack of Interoperability and Data Exchange	0.003
	Position	
BR1	High Cost of Implementation	0.005
BR5	Lack of Skill and Training	0.006
	Company Size	
BR4	Lack of Legal and Contractual Framework	0.042
BR6	Lack of Interoperability and Data Exchange	0.004
BR8	Lack of Standardization	0.014
	Working Experience	
BR1	High Cost of Implementation	0.041
BR5	Lack of Skill and Training	0.008

The findings of the Kruskal Wallis test for the barriers that undermine the enhancement of VM with BIM are shown in Table 4.8 and summarized as follows:

(A) The group of Developer agreed

(i) more towards BR1 – High Cost of Implementation (mean rank = 76.10) than group of Others (mean rank = 70.55), Consultant (mean rank = 68.04) and Contractor (mean rank = 51.18)

(ii) more towards BR3 – Lack of Awareness and Understanding (mean rank = 82.43) than group of Contractor (mean rank = 65.66), Others (mean rank = 62.73) and Consultant (mean rank = 58.13)

(iii) more towards BR5 – Lack of Skill and Training (mean rank = 75.60) than group of Consultant (mean rank = 69.61), Others (mean rank = 68.29) and Contractor (mean rank = 51.89)

(B) The group of C&S Engineer/ M&E Engineer agreed

(i) more towards BR1 – High Cost of Implementation (mean rank = 75.33) than group of Architect (mean rank = 71.27), Builder (mean rank = 68.94) and Quantity Surveyor (mean rank = 55.14).

(C) The group of Builder agreed

(i) more towards BR2 – Industry Resistance to Process Change (mean rank = 76.50) than group of C&S Engineer/ M&E Engineer (mean rank = 74.53), Architect (mean rank = 67.42) and Quantity Surveyor (mean rank = 55.36)

(D) The group of Quantity Surveyor agreed

(i) more towards BR6 – Lack of Interoperability and Data Exchange (mean rank = 80.20) than group of C&S Engineer/ M&E Engineer (mean rank = 65.91), Architect (mean rank = 56.83) and Builder (mean rank = 48.86)

(E) The group of Assistant Manager/Team Leader/Senior Executive perceived

(i) more towards BR1 – High Cost of Implementation (mean rank = 73.38) than group of Director/ CEO/ Contract Manager/ Head of Department (mean rank = 71.70) and Junior Executive/ Fresh Graduate (mean rank = 53.97).

(F) The group of Director/ CEO/ Contract Manager/ Head of Department perceived

(i) more towards BR5 – Lack of Skill and Training (mean rank = 74.27) than group of Assistant Manager/Team Leader/Senior Executive (mean rank = 72.65) and Junior Executive/ Fresh Graduate (mean rank = 53.02).

(G) The group of Company Size more than 75 people perceived

(i) more towards BR4 – Lack of Legal and Contractual Framework (mean rank = 78.20) than group of Company Size 31-75 people (mean rank = 65.61) and 0-30 people (mean rank = 59.74).

(ii) more towards BR6 – Lack of Interoperability and Data Exchange (mean rank = 81.19) than group of Company Size 31-75 people (mean rank = 67.27) and 0-30 people (mean rank = 56.56).

(iii) more towards BR8 – Lack of Standardization (mean rank = 81.46) than group of Company Size 0-30 people (mean rank = 61.16) and 31-75 people (mean rank = 61.02).

(H) The group of 3-5 years Working Experience perceived

(i) more towards BR1 – High Cost of Implementation (mean rank = 78.20) than group of 11-20 years (mean rank = 73.93), >21 years (mean rank = 73.13), 6-10 people (mean rank = 68.01) and 0-2 years (mean rank = 54.03).

(I) The group of >21 years Working Experience perceived

(i) more towards BR5 – Lack of Skill and Training (mean rank = 83.56) than group of 6-10 years (mean rank = 75.36), 3-5 years (mean rank = 70.56), 11-20 people (mean rank = 62.85) and 0-2 years (mean rank = 52.08).

4.7 Strategies to Encourage the Enhancement of VM with BIM

The mean rankings of the target respondents on the effectiveness of strategies to encourage the enhancement of VM with BIM in construction projects is presented in Table 4.9. The most effective strategies to encourage the enhancement of VM with BIM were ST4 - Provide Professional Training and Promotion Plan, ST3 - Establish a Start-up Funding Mechanism and ST5 - Include VM clauses and BIM in contracts. On the other hand, the least effective strategies to facilitate the enhancement of VM with BIM were ST1 - Conduct Conferences and Seminars and ST6 - Cooperation with educational institutions.

Table 4.9: Mean Ranking of the effectiveness of strategies in encouraging the enhancement of VM with BIM

Code	Statement	Mean Rank	Chi-square	Asymp. Sig.
ST4	Provide Professional Training and Promotion Plan	5.19	218.871	<.001
ST3	Establish a Start-up Funding Mechanism	5.13		
ST5	Include VM clauses and BIM in contracts	4.17		
ST2	Legislation and Government Involvement	3.94		
ST7	Standardized BIM implementation process	3.68		
ST1	Conduct Conferences and Seminars	3.29		
ST6	Cooperation with educational institutions	2.59		

Spearman's Rank Order Correlation Test is adopted to assess the connection between barriers of enhancing VM with BIM and strategies to encourage the enhancement of VM with BIM. Table 4.10 outlines the null hypothesis rejections regarding the correlation between barriers to using BIM to enhance VM and strategies to encourage using BIM to enhance VM.

Table 4.10 : Spearman Rank Correlation between Barriers of Enhancing VM with BIM and Strategies to Encourage the Enhancement of VM with BIM

	High Cost of Implementation	Industry Resistance to Process Change	Lack of Awareness and Understanding	Lack of Legal and Contractual Framework	Lack of Skill and Training	Lack of Interoperability and Data Exchange	Data Privacy and Security Issues	Lack of Standardization	Total number of sig. correlations
Conduct Conferences and Seminars	.214*	.059	.145	.133	-.026	.316**	.165	.142	2
Legislation and Government Involvement	.287**	.305**	.248**	.358**	.199*	.007	.247**	.171*	7
Establish a Start-up Funding Mechanism	.559**	.437**	.139	.104	.292**	-.125	.119	-.088	3
Provide Professional Training and Promotion Plan	.383**	.373**	.203*	.070	.363**	0.058	.085	.167	4
Include VM clauses and BIM in contracts	.311**	.346**	.232**	.281**	.122	.125	.164	.229**	5
Cooperation with educational institutions	-.067	-.119	.172*	.201*	.046	.420**	.260**	.330**	5
Standardized BIM implementation process	.049	.133	.257**	.116	.104	.271**	.279**	.506**	4

Note: *. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The findings of the Spearman rank-order correlation between barriers of enhancing VM with BIM and strategies to encourage the enhancement of VM with BIM presented in Table 4.10 are summarized as follows:

(A) Conduct Conferences and Seminars is the strategy associated with 2 correlations, namely High Cost of Implementation and Lack of Interoperability and Data Exchange

(B) Legislation and Government Involvement is the strategy associated with 7 correlations, namely High Cost of Implementation, Industry Resistance to Process Change, Lack of Awareness and Understanding, Lack of Legal and Contractual Framework, Lack of Skill and Training, Data Privacy and Security Issues and Lack of Standardization.

(C) Establish a Start-up Funding Mechanism is the strategy associated with 3 correlations, namely High Cost of Implementation, Industry Resistance to Process Change and Lack of Skill and Training.

(D) Provide Professional Training and Promotion Plan is the strategy associated with 4 correlations, namely High Cost of Implementation, Industry Resistance to Process Change, Lack of Awareness and Understanding and Lack of Skill and Training.

(E) Include VM clauses and BIM in contracts is the strategy associated with 5 correlations, namely High Cost of Implementation, Industry Resistance to Process Change, Lack of Awareness and Understanding, Lack of Legal and Contractual Framework and Lack of Standardization.

(F) Cooperation with educational institutions is the strategy associated with 5 correlations, namely Lack of Awareness and Understanding, Lack of Legal and Contractual Framework, Lack of Interoperability and Data Exchange, Data Privacy and Security Issues and Lack of Standardization.

(G) Standardized BIM implementation process is the strategy associated with 4 correlations, namely Lack of Awareness and Understanding, Lack of Interoperability and Data Exchange, Data Privacy and Security Issues and Lack of Standardization.

Table 4.10 shows the strength of the coefficients between barriers to utilizing BIM to enhance VM and strategies that encourage utilizing BIM to enhance VM as follows:

(A) Strong Correlation (0.69 ⩾ ρ ⩾ 0.4)

(i) **Establish a Start-up Funding Mechanism** and **High Cost of Implementation** are strongly correlated at a significance level of 0.559.

(ii) **Standardized BIM implementation process** is strongly correlated with **Lack of Standardization** at the significant level of 0.506.

(iii) **Establish a Start-up Funding Mechanism** and **Industry Resistance to Process Change** are strongly correlated at a significance level of 0.437.

(iv) **Cooperation with educational institutions** and **Lack of Interoperability and Data Exchange** are strongly correlated at a significance level of 0.420.

(B) Negative Correlation

(i) **Establish a Start-up Funding Mechanism and Lack of Interoperability and Data Exchange** are negatively correlated at a significance level of -.125.

(ii) **Cooperation with Educational Institutions** and **Industry Resistance to Process Change** are negatively correlated at a significance level of -.119.

(iii) **Establish a Start-up Funding Mechanism** and **Lack of Standardization** are negatively correlated at a significance level of -.088.

(iv) **Cooperation with educational institutions** and **High Cost of Implementation** are negatively correlated at a significance level of -.067.

4.8 Discussion

The discussion of the study consists of four distinct sections, which include (1) Agreement on the Advantages of Enhancing VM with BIM, (2) The Usage of Enhancing VM with BIM, (3) Barriers of Enhancing VM with BIM and (4) Strategies to Encourage the Enhancement of VM with BIM.

4.8.1 Optimizing Project Outcomes is the key advantage of Using BIM to Enhance VM

According to the results of Table 4.3 and 4.4, the top three agreement ranked by the participants were BE/BP9 – The enhancement of VM with BIM leads to better choices and optimizes project outcomes, BE/BP2 – The enhancement of VM with BIM improves collaboration and communication among project stakeholders and BE/BP5 –The enhancement of VM with BIM improves work productivity and quality. The extent of agreement regarding the advantages of enhancing VM with BIM is positively associated with the level of agreement concerning the advantages experienced in ongoing/past construction project through the utilization of BIM to enhance VM. Therefore, enhancing VM practices with BIM plays an important role in improving project outcomes, collaboration, productivity and quality in the construction industry.

The advantages that received the highest agreement from respondents are leading to better choices and optimized project outcomes. By adopting BIM in VM practice, project stakeholders have access to comprehensive data and visualizations that facilitate informed decision-making throughout the project lifecycle (Punnyasoma et al., 2019). This enables them to evaluate various design and construction options more effectively and select those that offer the greatest value to optimize project outcome. Besides, BIM facilitates accurate cost estimation and analysis to identify cost-saving opportunities (Raza et al., 2023). When BIM is adopted in VM practice, the process prioritizes value-driven decisions to maximize project benefits within budget constraints. On the other hand, the fact that "The enhancement of VM with BIM increases client satisfaction" received the lowest agreement among respondents. This indicates a lack of consensus among respondents regarding the positive impact of enhancing VM with BIM on customer satisfaction in construction projects. Thus, the findings suggest that respondents rarely observe or experience client satisfaction when using BIM to enhance VM in ongoing or past construction projects.

In addition, BE/BP9 – “The enhancement of VM with BIM leads to better choices and optimizes project outcomes” has been identified as the benefits of using BIM to enhance VM with the highest agreement from the respondents. BIM utilizes a digital and collaborative representation of built assets that streamlines the design, construction, and operations phases to provide a reliable basis for decision-making (Schamne et al., 2024). With access to detailed information about the project's components, stakeholders can evaluate various options more effectively and make decisions during the VM process to optimize project outcomes. BIM enables stakeholders to visualize and simulate from the design phase to the post-construction phase, allowing them to assess the potential impact of various decisions on project performance and objectives (Nikologianni et al., 2023). They can assess the implications of each decision on cost, time, and quality, ultimately striving for the most favorable project outcomes.

Furthermore, the majority of respondents agreed that BE/BP2 – "The enhancement of VM with BIM improves collaboration and communication among project stakeholders" and BE/BP5 – "The enhancement of VM with BIM improves work productivity and quality". BIM serves as an intelligent digital platform that enables seamless collaboration among stakeholders and facilitates information exchange (Waqar et al., 2023). By using BIM in the VM process, different stakeholders, including architects, engineers, contractors and clients, have access to the same accurate data. Consistency of data among respondents enables them to collaborate more effectively and reduce miscommunication. They can also easily share information, exchange feedback and resolve conflicts in the early stages of a project. This collaborative environment promotes more productive discussions and fosters consensus, resulting in increased project productivity. Besides, the adoption of BIM in the VM process enhances construction planning, thus reducing rework and time waste (Shaqour, 2022). By understanding where conflicts may occur in sequencing and scheduling, project teams can adjust the construction sequence to mitigate potential conflicts and optimize efficiency. Efficient planning and coordination can improve productivity and quality, thereby reducing rework and delays during construction.

4.8.2 The Enhancement of VM with BIM is utilized throughout the Construction Project Lifecycle

(a) Creating visualizations to help clients better understand the project is the primary application for using BIM to enhance VM

Referring to Table 4.5, the main usage of VM enhancement with BIM is SS7 - *"The BIM model in my project is used to create visualizations that help clients better understand the project"*. Tang and Liu (2022) argued that in the construction industry, poor communication between the client and the project team is a major issue that can lead to misunderstandings, misaligned expectations, and ultimately an unsuccessful project outcome. To solve the problem, BIM is embraced as an innovative technology that significantly impact communication and facilitate collaboration among project stakeholders.

According to Olanrewaju et al. (2022), BIM was adopted for its inherent visualization capabilities, allowing clients to preview their proposed projects before construction begins. These visual representations allow stakeholders to quickly grasp complex concepts and identify areas for improvement, leading to more efficient workflows and reduced rework. Besides, 3D BIM provides a comprehensive representation of the building model in three dimensions, giving clients a more immersive and comprehensive understanding of the project (Raza et al., 2023). By visualizing elements such as building structure and spatial layout, clients can gain clear insights into how the final project will look and function. The visualization capability of BIM helps bridge the communication gap between project stakeholders, enabling clients to make more informed decisions that optimize project outcomes.

Subsequently, another major usage for enhancing VM with BIM is SS5 – "*We conduct cost-benefit analysis of the construction project during the VM/VE process*". Controlling costs is crucial for the success of construction projects, which often consume significant financial resources due to various challenges and inefficiencies encountered during the construction process (Baarimah et al., 2021). In construction projects, VE is used for a variety of purposes, including analyzing the functionality and cost control of new projects and materials, and evaluating green building practices to minimize construction and energy expenditures. By systematically evaluating the costs and benefits associated with various project alternatives, stakeholders can make informed decisions that maximize value and optimize project outcomes. For example, the cost of using high-quality materials may be higher initially, but the long-term benefits, such as reduced maintenance costs, could outweigh the initial investment (Punnyasoma et al., 2019). Additionally, investing in advanced construction technologies or methods may increase upfront costs but can save time and increase efficiency during the construction process (Shirley et al., 2020). Therefore, cost-benefit analysis can improve work productivity and quality by identifying the long-term benefits and potential cost savings associated with the adoption of advanced construction technologies or methods.

In addition, it is noteworthy that SS1 – *"My company practises post project review whenever the construction project is completed"* was ranked by the respondents as one of the main usages for using BIM to enhance VM. Post-project review is widely used after the completion of a construction project as a means to capture and disseminate knowledge among project participants (Carrillo et al, 2011). It is a formal assessment of a project conducted to extract valuable lessons that can be applied to future projects. The process involves a reflective analysis by the project team to learn from past activities, prevent errors, and draw from both successful and unsuccessful experiences for future endeavors. In the post-project review, the key stakeholders reviews and discusses the project's results (Abubeker and Asnake, 2021). This collaborative approach promotes a culture of transparency, trust, and accountability, enhancing collaboration and communication among project team members. In addition, based on the results of the post-project review, recommendations for process improvements, best practices, and corrective actions can be developed to improve future project performance. Furthermore, Oyewobi et al. (2019) discussed that conducting post-project reviews can improve work productivity and quality by identifying areas for improvement in project execution and resource allocation. By leveraging the insights gained from the review process, project teams can take steps to streamline workflows, increase efficiency, and optimize resource utilization, ultimately improving project outcomes and improving the quality of deliverables.

(b) BIM is mostly used in VM/VE practice by Practitioners working in Consulting firm to Enhance Communication and Coordination

In term of the business activities of respondents, there are significant differences between those engaged in consulting firms, property development, contracting business and other types of business activities. According to the results of the Kruskal-Wallis H test in Table 4.6, respondents working in consulting firms have a higher mean ranking for the usage of enhancing VM with BIM, including SS6 – *"My company practises BIM in the construction project"*, SS9 – *"We use BIM software to enhance communication and coordination among project stakeholders"* and SS11 – *"We use BIM software during the VM/VE process"*.

The rationale is practitioners working in consulting firms often specialize in providing professional services related to project management, design, and engineering (Sarda and Dewalkar, 2016). During the construction process, their responsibilities include dealing with factors such as scheduling, cost estimating, risk identification, and ongoing monitoring. They rely on expertise in advanced technologies such as BIM to effectively manage these factors and improve project delivery. In addition, consulting firms typically work closely with a variety of project stakeholders, including clients, architects, engineers, and contractors (Nikumbh and Pimplikar, 2014). To facilitate better communication and coordination among project stakeholders in VM practices, consulting firms often adopt BIM to centralise project information. Therefore, the practitioners working in consulting firms often have expertise in the use of BIM software and its application in construction projects in order to effectively use BIM for VM purposes.

(c) Architects adopts BIM in VM/ VE practise more than others to Monitor the Entire Building Lifecycle.

From a professional perspective, architects, C&S engineers, M&E engineers, quantity surveyors, and builders are very different from one another. Referring to the results in Table 4.6, architects were reported to have a higher mean ranking for the usage of enhancing VM with BIM, including SS6 – *"My company practises BIM in the construction project"*, SS8 – *"We use BIM tools to monitor the entire building lifecycle"* and SS11 – *"We use BIM software during the VM/VE process".*

According to Patel et al. (2023), architects require planning and designing expertise because they are often at the forefront of the design process and are primarily involved in the initial stages of project planning. As a result, they may gain a deeper understanding of the potential benefits of incorporating BIM into the design and planning phases. By leveraging BIM during the VM/VE process, architects can analyze design alternatives, optimize project costs, and improve overall project efficiency. Moreover, architects are responsible for overseeing construction projects from initial conception to completion, ensuring that they meet high standards of quality and safety (Chigozie et al., 2015). This aspect involves the use of BIM to provide valuable data for the ongoing management and operation of buildings after construction. Architects can leverage BIM to ensure that the building design and construction align with the long-term maintenance and operational needs of the facility, thus monitoring its entire lifecycle from conception through operation. Given that architects have a responsibility to protect the public from potential risks associated with design or construction defects, they are inclined to use BIM tools in VM practices throughout the entire building life cycle.

(d) Practitioners with more experience and higher positions focus more on post-project review after project completion.

On top of that, a subset of respondents with more than 20 years of working experience and serving in senior positions such as CEO, Director, Contract Manager, or Head of Department expressed a higher level of agreement with SS1 – *"My company practises post project review whenever the construction project is completed."* According to Olatunji and Oke (2014), practitioners with extensive work experience and higher position often possess a deeper understanding of the importance of their roles in the construction industry. Their years of experience have allowed them to develop a strong sense of professionalism and dedication to their jobs. As a result, they place greater emphasis on value practices such as post-project reviews as important tools for continuous improvement and ensuring project success. During post-project reviews, they can leverage past experiences to identify areas for improvement, anticipate potential challenges, and implement solutions to improve future project outcomes. Therefore, they tend to implement post-project reviews because they have witnessed the benefits of post-project reviews throughout their careers.

In addition, the majority of respondents with 6-10 years and 11-20 years working experience are more perceived towards SS4 – *"We identify and prioritize the key values and objectives for the construction project during the VM/VE process."* and SS13 – *"We make BIM as mandatory for the VM/VE study."* Practitioners within this range of experience are likely to have some understanding of VM principles and practices for working in the construction industry (Sarda and Dewalkar, 2016). They have experienced a variety of projects and developed a nuanced understanding of the importance of defining clear goals and values for project success. Additionally, as the construction industry evolves towards more advanced technologies and methodologies, experienced professionals are more aware of the benefits of integrating BIM and VM/VE processes into project workflows. They recognize that BIM is a valuable tool for enhancing VM/VE processes and project outcomes.

4.8.3 High cost of Implementation Remains the Main Barrier that Undermines the Enhancement of VM with BIM

(a) Barriers of Enhancing of VM with BIM

As shown in Table 4.7, the first ranked barrier of the enhancement of VM with BIM is BR1 - High Cost of Implementation. According to Siebelink et al. (2021), at the operational level, the significant expenses related to software and hardware, as well as the costs involved in educating and training staff, and establishing BIM workflows, have been recognised as barriers to the use of BIM in VM process. The cost of purchasing new software depends on the capabilities of a company's existing IT infrastructure, which poses a potential barrier, especially for smaller companies or companies with limited financial resources. BIM software often requires licensing fees, ongoing software updates and support service subscription fees, which can place a considerable financial burden on a company (Ismail et al. 2021). At the outset of the investment, the company must bear these initial costs, which are often not recouped due to the relatively low fees associated with the project and construction documents (Leśniak et al., 2021). Additionally, there is a lack of co-financing or subsidies specifically for the implementation of BIM technologies in construction processes that would have helped SMEs adopt and launch modeling in virtual cloud environments. The absence of financial support further hampers their ability to adopt BIM to enhance VM effectively.

Besides, BR2 - Industry Resistance to Process Change is one of the significant barriers that confronted by the respondents. The adoption of BIM to enhance VM process typically requires a fundamental shift in procedures and principles within the construction industry (Babatunde et al., 2021). However, the construction industry has historically relied on traditional methods and practices, making it extremely difficult to embrace new processes. It is well known that the introduction of new technologies and processes such as BIM requires a break from familiar approaches, which may encounter resistance from stakeholders accustomed to traditional workflows. Olanrewaju et al. (2020) study on the effective use of BIM to enhance VM requires comprehensive alterations across all aspects of a company's operations and business model. However, some professionals and companies are concerned about these sweeping changes because they do not have the confidence to implement and effectively manage such transitional shifts. This can create uncertainty and a fear of disruption among industry professionals who are hesitant to embrace new ways of working.

In addition, the result discloses that one of the key barriers is BR5 - Lack of Skill and Training. According to Liu et al. (2015), the enhancement of VM with BIM is a sophisticated technology that requires specialized skills and training to use effectively. Many construction professionals may lack the requisite expertise to navigate BIM software and workflows proficiently. Moreover, a significant factor contributing to a shortage of skilled workers in the adoption of BIM to enhance VM is the inadequate training provided on BIM applications for young and recently graduated employees (Siebelink et al., 2021). This is because providing a comprehensive training program for the enhancement of VM with BIM can be resource-intensive, which requires significant investments of time, cost, and personnel. Even with training programs in place, some professionals may be resistant to learning new technologies and methods, especially if they have been accustomed to traditional practices for a long time (Chan et al., 2019). This problem contributes to a shortage of skilled practitioners and hinders the use of BIM to enhance VM.

(b) High Implementation Cost, Lack of Awareness and Understanding and Lack of Skill and Training make Property Development Firms face greater challenges in adopting BIM to enhance VM

According to the result of the Kruskal-Wallis H test in Table 4.8, there are considerable disparities between those engaged in consulting firms, property development, contracting business and other types of business activities. Referring to the results in Table 4.8, the respondents who work for property development firms are more agreed BR1 - High Cost of Implementation, BR3

- Lack of Awareness and Understanding and BR5 - Lack of Skill and Training as the barrier to the enhancement of VM with BIM.

The reason is that property development companies are directly involved in the financial aspects of construction projects (Chan et al., 2017). For property development projects, they usually demand large upfront expenditures for infrastructure, building, and site acquisition. The costs associated with implementing BIM technology, including software, hardware and training, represent a significant financial burden for them. Besides, property development firms manage all stage of a building project's life cycle, from planning and design to construction and delivery (Hussain, 2023). They understand the importance of effective project management and recognize that a lack of awareness and understanding of BIM and VM processes among project stakeholders can lead to communication gaps, inefficiencies, and delays. In addition, property development companies prioritize delivering quality projects on time and within budget (Muntasir, 2024). They may view a lack of BIM skills and training as a barrier to ensuring the accuracy and efficiency of VM processes that are critical to maintaining project quality and meeting client expectations.

Furthermore, the practitioners with more than 21 years of working experience or those holding senior positions such as Director, CEO, Contract Manager, or Head of Department identified BR5 - Lack of Skill and Training as a barrier to enhancing VM with BIM. Senior professionals oversee project execution and are responsible for delivering successful results (Crawford, 2005). They recognize that effective implementation of BIM in VM process requires a well-trained and skilled workforce capable of realizing the full potential of the technology. Additionally, experienced professionals have a high level of awareness of project risks and challenges. They understand that a lack of skills and training can lead to project delays, cost overruns and quality issues, posing significant risks to project success.

On the other hand, the respondents with 3-5 years of working experience or in positions such as Assistant Manager, Team Leader, or Senior Executive perceived BR1 - High Cost of Implementation as a barrier to enhancing VM with BIM. Practitioners in mid-level positions may face a lack of organizational support and resources dedicated to BIM implementation and training programs (Durdyev et al., 2022). They may weigh the benefits of the enhancement of VM with BIM against the costs involved. They are sensitive to the potential return on investment and skeptical of the direct benefits of investing in BIM training, especially if the costs are perceived as high and the benefits are not clearly demonstrated. The perceived high implementation cost may deter them from pursuing opportunities to enhance their skills in BIM to enhance VM practise.

(c) Large-sized Firms faced more Barriers in terms of Legal and Contractual Framework, Interoperability and Data Exchange and Standardization.

According to the results of Kruskal-Wallis H test in Table 4.8, respondents employed in large-sized companies (with over 75 employees) exhibit a higher level of agreement regarding the barriers that undermines the enhancement of VM with BIM compared to those in micro-sized or small-sized companies and medium-sized companies, including BR4 – Lack of Legal and Contractual Framework, BR6 – Lack of Interoperability and Data Exchange and BR8 – Lack of Standardization. Previous research has found that large-sized companies typically engage in broader and more complex projects that involve multiple stakeholders, diverse technologies, and varied contractual arrangements (Lehtinen et al., 2019). As a result, they may face greater challenges related to legal and contractual frameworks, interoperability and standardization, which are critical to effectively managing the complexity and scale of their operations. Large-sized companies typically operate in multiple jurisdictions and are subject to a broader range of regulatory requirements related to legal and contractual frameworks. However, there is currently a lack of specific contractual forms and legal frameworks related to the use of BIM and VM in Malaysia (Jo, 2018). The practitioners perceive a lack of clarity in these regulations as a significant barrier to compliance, potentially exposing them to legal risks and liabilities. Additionally, large-sized companies often rely on the seamless exchange of information and data between different departments, teams, and external partners. A lack of interoperability and standardized data exchange protocols can hinder their ability to collaborate effectively, leading to operational inefficiencies and project delays.

4.8.4 Establish a Start-up Funding Mechanism as the Key Strategy that Encourage the Enhancement of VM with BIM

Referring to the findings of the Spearman's rank-order correlation test in Table 4.10, the finding revealed that ST3/BR1 and ST7/BR8 have a strong correlation with the highest significance level. However, ST6/BR2 and ST3/BR6 have an inverse relationship, with the lowest negative values.

It is observed that ST3 - Establish a Start-up Funding Mechanism and BR1 - High Cost of Implementation are strongly correlated at a significance level of 0.559. The findings obtained by Ismail et al. (2021) noted that cost is a significant barrier to BIM adoption among Malaysian SME contractors. Adopting BIM in VM practise requires significant investment, including the cost of purchasing BIM software and hardware, providing comprehensive training for employees and meeting specific certification and licensing requirements. Therefore, establishing a start-up funding mechanism can help alleviate this financial barrier by providing financial assistance and support to organizations seeking to adopt BIM in VM practices. Additionally, some AEC companies are reluctant to make subtantial investments in technology, software, or training, often because of concerns about the possibility of a quick return on investment (Takyi-Annan and Zhang, 2023). As a result, financing mechanisms can provide financial support and help mitigate the financial risks associated with BIM adoption, making it more feasible for companies to adopt BIM to enhance VM practise.

Furthermore, ST7 - Standardized BIM implementation process is strongly correlated with BR8 - Lack of Standardization at the significant level of 0.506. The lack of standardization in BIM and VM practices is a recognised barrier that hampers their widespread adoption and effective implementation within the construction industry (Chan et al., 2019). To directly address this barrier, organizations can standardize BIM implementation in VM practices by establishing unified practices and protocols for its usage. Besides, standardized BIM implementation processes ensure consistency and efficiency in project delivery by streamlining workflows, enhancing communication, and facilitating collaboration among project participants (Nikologianni, 2022). This helps overcome the challenges posed by a lack of standardization and promotes smoother project execution. BIM implementation in the VM process is standardized to ensure quality assurance through clearly defined usage guidelines, procedures and best practices. This reduces the risk of errors, inconsistencies and rework, thereby improving project outcomes and increasing client confidence and satisfaction.

In contrast, ST3 - Establish a Start-up Funding Mechanism and BR6 - Lack of Interoperability and Data Exchange showed an inverse relationship with a significance level of -.125. Interoperability is a significant barrier to BIM implementation in the global AEC industry due to incompatible software platforms, data formats, or communication protocols (Chan et al., 2019). To overcome this barrier, startup financing mechanisms enable small businesses with limited financial resources to obtain the resources they need to grow their businesses. When additional financial support is obtained from financing mechanisms, companies can invest in upgrading their facilities related to BIM technology and VM processes to improve interoperability and data exchange issues. Besides, Shaqour (2022) claimed that challenges and failures in project integration and communication management can be addressed through increased investment in facilities. Organizations can employ advanced technologies and tools to facilitate seamless communication and integration between different software platforms and project stakeholders. This enables smoother coordination, collaboration and information sharing throughout the project lifecycle.

Furthermore, there is an inverse relationship between ST6 - Cooperation with Educational Institutions and BR2 - Industry Resistance to Process Change with a significance level of -.119. According to Ankrah et al. (2015), the collaborations between universities and industry are increasingly viewed as a means to foster innovation by facilitating the exchange of knowledge. Collaborations with educational institutions often expose industry professionals to new ideas and techniques developed through research and academic collaborations. Such collaboration can foster a culture of innovation and openness to change, thereby reducing resistance to process change within the industry. In addition, the primary obstacles to BIM implementation are identified as insufficient professional expertise and challenges in adapting work processes or training personnel (Chen et al., 2022). This suggests that industry should work with educational institutions to provide opportunities for knowledge transfer and training, enabling industry stakeholders to acquire new skills and competencies. As professionals become more familiar with emerging practices and technologies, their resistance to process changes consistent with these innovations and advances may weaken.

In addition, based on the results in Table 4.9, ST4 - Provide Professional Training and Promotion Plan is considered one of the effective strategies to encourage the use of BIM to enhance VM, receiving the highest recognition from respondents. According to Othman et al. (2021), attending in training sessions enriches participants' theoretical understanding, while technical practice enhances their practical skills and knowledge. Therefore, practitioners believe that professional training is essential to improving the skills and abilities needed to effectively utilize BIM in VM practice. This is because investing in training programs allows industry professionals to gain the knowledge and expertise to leverage BIM for VM practices. Besides, promotion activities such as workshops and awareness campaigns can educate stakeholders and increase their awareness of the benefits of using BIM to enhance VM (Olanrewaju *et al.*, 2022). By raising awareness and fostering a better understanding of BIM's capabilities, organizations can encourage its adoption and implementation in construction projects. Moreover, implementation of BIM to enhance VM processes often requires a cultural shift within organizations. Professional training and promotion plans can facilitate this change by providing employees with the necessary skills, knowledge and motivation to embrace BIM and VM practices and integrate them into their work processes.

Subsequently, it can be inferred that another most recognised strategic to encourage the enhancement of VM with BIM is ST3 - Establish a Start-up Funding Mechanism. Many SMEs, including start-ups, face a lack of additional financial support to invest in BIM implementation, which hinders their ability to adopt new technologies (Chen et al., 2022). By establishing financing mechanisms specifically tailored for start-ups, organizations can reduce the financial burden associated with acquiring BIM software, hardware, and training, making it more accessible to a wider range of businesses. The funding support provided for BIM adoption can encourage start-ups to incorporate innovative practices like VM practices into their projects, thereby driving innovation and improvement across the industry. For example, Patel et al. (2023) found that the initial cost of implementing BIM to enhance VM can be prohibitive for start-ups, preventing them from adopting the technology. Therefore, financial assistance provided through start-up funding mechanisms can lower the entry barriers for small enterprises, allowing them to compete fairly with large enterprises with strong financial resources.

Furthermore, it is noteworthy that ST5 - Include VM clauses and BIM in contracts was listed by respondents as one of the recommended strategies for disseminating the enhancement of VM with BIM. Olanrewaju et al. (2022) believed that the adoption of BIM faces various barriers, including insufficient attention to legal and organizational issues that hinder its implementation, as well as mismatches between individuals, procedures, technologies and processes. Therefore, including specific clauses related to VM and BIM in contracts allowed organizations to establish legal obligations and frameworks that govern the use and implementation of these technologies in construction projects. This provides clarity and assurance to all parties involved regarding their roles and responsibilities related to the implementation of VM and BIM. In addition, VM and BIM provisions in contracts help mitigate risks associated with project delivery by addressing potential issues related to data management, collaboration, and project performance (Celik et al., 2023). By establishing clear guidelines and protocols for VM and BIM use, organizations can minimize disputes, delays, and cost overruns, thereby enhancing project outcomes and reducing overall project risk.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter includes a comprehensive summary of the results related to the aims and objectives of the study. Next, the research implications and limitations are discussed. Lastly, some recommendations for future studies have been proposed to facilitate the enhancement of VM with BIM.

5.2 Accomplishments of Research Objectives

The construction industry often faces issues such as poor quality, ineffective communication, cost overruns and project delays. The industry is a growing number of problems, resulting in a lot of implications for construction projects. VM is considered a key strategy to solve the above-mentioned problems faced by the construction industry, and BIM helps to obtain the basic and specific project data required for the enhancement of VM process. Therefore, this study is crucial to better understanding current practices for using BIM to enhance VM, making construction practitioners more accepting and confident in leveraging BIM to enhance VM. This research also identified the most recognised benefits of using BIM to enhance VM and highlighted the most acknowledged benefits incurred in the ongoing/past construction project. Furthermore, the results offer industry professionals useful information on the main barriers to using BIM to enhance VM, as well as effective strategies to encourage the use of BIM to enhance VM. The research objectives were achieved and concluded as follows:

5.2.1 Objective 1: To identify the advantages incurred from the enhancement of VM with BIM

The study has explored and examined a total of 13 advantages associated with enhancing VM with BIM, which were initially identified through literature review. Many topics covered by the advantages, including "Accelerate Project Delivery Time", "Enhance Collaboration and Communication", "Precise Cost

Estimates and Control", "Energy Efficiency and Sustainability", "Improve Work Productivity and Quality", "Efficient Construction Planning and Management", "Maintain the Construction Schedule", "Improve Decision-making", "Risk Identification and Mitigation", "Increase Client Satisfaction", "Better Choice and Optimized Project Outcome", "Avoid Costly Mistakes" and "Facility Management and Operation".

The three arguments that had the highest mean rating, as per the results, are "The enhancement of VM with BIM leads to better choices and optimizes project outcomes", followed by "The enhancement of VM with BIM improves collaboration and communication among project stakeholders" and "The enhancement of VM with BIM improves work productivity and quality". These statements above reflect the advantages most widely recognised by respondents and occur more frequently in ongoing/past construction projects.

Besides, the main application of using BIM in VM practice is to create visualizations to help clients better understand the project, contribute to better choices and optimized project outcomes, improve collaboration and communication, and increase work productivity and quality. The reason is that using BIM in VM practice to create visualizations can give clients a clearer understanding of the project, thereby promoting informed decision-making and optimizing project outcomes while minimizing misunderstandings. Consequently, this improves work productivity and quality by facilitating smoother decision-making and reducing errors. The visualization capabilities of BIM can also improve collaboration and communication among project stakeholders by promoting more effective discussion and coordination of project goals and priorities.

In addition, the findings discovered that practitioners working in consulting firms tend to use BIM in VM practices to enhance communication and coordination. This is because of the complexity and scale of projects they handle, requiring efficient collaboration among various stakeholders. Furthermore, architects are more inclined to adopt BIM in VM/VE practice to monitor the entire building life cycle because BIM provides data that can be used for the ongoing management and operation of the building, and aligns design with long-term maintenance and operation requirements.

5.2.2 Objective 2: To investigate the barriers of enhancing VM with BIM

This research identified 8 barriers that hinder the enhancement of VM with BIM. These barriers resulted from a literature review and were investigated in the study. These barriers consist of "High Cost of Implementation", "Industry Resistance to Process Chang", "Lack of Awareness and Understanding", "Lack of Legal and Contractual Framework", "Lack of Skill and Training", "Lack of Interoperability and Data Exchange" , "Data Privacy and Security Issues" and "Lack of Standardization".

The result indicated that the three most significant barriers that undermine the enhancement of VM with BIM are high cost of implementation, industry resistance to process change and lack of skill and training. The rationale is that the financial aspects may impact an organization's ability to invest in training programs to develop the necessary skills, while cultural barriers may hinder efforts to allocate resources towards implementation.

Besides, the results showed that respondents who are employed by large enterprises or property development firms are more likely to recognise the barriers that hinder the enhancement of VM with BIM. The reason behind is that practitioners working in property development firms focus on the financial aspects and project management of construction projects to ensure quality, timely delivery, and adherence to budget, which makes them more likely to recognize the barriers to implementating BIM in VM process. Simultaneously, large-sized companies often involved in broad and complex projects involving numerous stakeholders and disparate technologies, leading them to often encounter challenges in using BIM and VM practices to effectively manage operational complexity.

5.2.3 Objective 3: To propose the strategies on disseminating the enhancement of VM with BIM

This research delved into 7 strategies on disseminating the enhancement of VM with BIM, which were emerged from a literature review and examined in the study. These strategies consist of "Conduct Conferences and Seminars", "Legislation and Government Involvement", "Establish a Start-up Funding Mechanism", "Provide Professional Training and Promotion Plan", "Include

VM clauses and BIM in contracts", "Cooperation with educational institutions" and "Standardized BIM implementation process".

The results showed that the three most important strategies are provide professional training and promotion plan, establish a start-up funding mechanism and include VM clauses and BIM in contracts. This is because professional training and promotion plans can equip stakeholders with necessary skills, while a start-up funding mechanism can facilitate implementation. Besides, incorporating VM clauses and BIM requirements into contracts can ensure their seamless integration into project processes and practices.

In addition, the finding showed a strong correlation between high cost of implementation and establish a start-up funding mechanism, as well as lack of standardization and standardized BIM implementation process. This indicates that high implementation costs are closely associated with the necessity for funding support, while the absence of standardization highlights the importance of implementing standardized processes in BIM utilization. On the other hand, there is an inverse relationship between cooperation with educational institutions and industry resistance to process change, as well as the establishment of a start-up funding and lack of interoperability and data exchange. In essence, fostering collaboration with educational institutions may contribute to reducing resistance to change within the industry, while securing start-up funding could help address challenges related to interoperability and data exchange.

5.3 Research Implications

The research contributes to a deeper understanding of the application prospects of BIM in VM practices among construction practitioners. It is expected that the results will function as a guide to enhance VM practices with BIM.

First and foremost, this study provides valuable insights for construction professionals to anticipate the trajectory of BIM adoption in VM practices. It equips construction companies with the foresight to recognize the future potential for enhancing VM with BIM. This foresight enables the company to stay ahead of the curve and remain competitive in an evolving market. The information from the research would greatly increase awareness within the construction industry, helping them to overhaul their existing processes and identify areas for improvement. This leads to more efficient workflows, reduced costs, and improved project outcomes. Besides, this study helps construction professionals better understand the barriers that undermine the enhancement of VM with BIM, allowing them to identify the most crucial barriers that require careful consideration during the implementation of BIM to enhance VM. By identifying these barriers, companies can develop strategies to overcome them and facilitate smoother BIM adoption. The study highlights effective strategies to address barriers to motivate the construction stakeholders to incorporate BIM into their project to enhance VM. As a result, the overall findings can help the top management of organizations in developing strategic plans to drive the BIM adoption in VM practices across the company. This strategic planning ensures alignment with organizational goals and objectives, maximizing the impact of BIM on VM.

Furthermore, the findings inform universities about the specific needs and challenges practitioners face in implementing BIM within VM practices. This insight will be valuable in updating and refining existing courses to include relevant and up-to-date content. By gaining a deeper understanding of practitioner needs, universities can tailor their education programs to provide students with the necessary skills and knowledge to meet the real-world challenges of the construction industry. This may involve integrating coursework, projects and practical experience with a focus on BIM implementation in VM practice. By providing training on the integration of BIM and VM, universities ensure that their graduates are equipped with practical skills that are in demand in the construction industry. This not only improves the employability of graduates but also helps bridge the gap between academia and industry needs. Universities that embrace the innovative pratice in their educational programs gain a competitive advantage by producing graduates who are well-prepared to meet the evolving demands of the construction industry. This attracts potential students seeking cutting-edge training and enhances the reputation of the institution.

Furthermore, this research helps regulatory agencies to develop and implement proactive and effective strategies and protocols to enhance VM using BIM in the construction sector. By understanding the specific needs, benefits, and barriers identified in the research, policymakers can design initiatives that support and encourage the adoption of BIM in VM processes. Policymakers can use the findings to inform policy development related to construction industry standards and regulations. This includes considerations for updating existing standards or creating new regulations that reflect the advancements and potential benefits of BIM integration in VM practices. They can design policies that address the identified challenges to help industry stakeholders overcome barriers to adoption, such as technological limitations or resistance to change. In addition, policymakers can promote innovation in the construction sector by aligning policies with the proposed dissemination strategies. This includes investing in training programs, funding research initiatives, and creating incentives for industry stakeholders to adopt BIM in VM practice.

Last but not least, this research enriches the body of knowledge by generating comprehensive insights related to the enhancement of VM with BIM. The research identifies the usage of the enhancement of VM with BIM and its benefits, providing empirical evidence on how BIM enhances various aspects of VM processes. This contributes to a deeper understanding of the potential value and benefits of the practice. Additionally, the research identifies practical challenges in implementing VM enhancement with BIM and proposes feasible dissemination strategies based on best practices and practical insights. These valuable insights and recommendations are intended to advance knowledge in the field and inform future research and practice.

5.4 Research Limitations

There were significant barriers due to insufficient time during the data collection phase. This limitation has resulted in incomplete and inconsistent data across various demographic backgrounds of respondents. In this study, the data gathered for the C&S Engineer group consisted of only 20 samples, while the M&E Engineer group had only 17 samples, both of which were less than the minimum of 30 samples that is advised for reliable statistical analysis. Besides, fewer builders make up the total than the suggested sample size of 30. Consequently, it was decided to merge the C&S Engineer group with the M&E Engineer group due to this limitation. The decision was made to boost the sample size and adhere to the CLT, stating that larger sample sizes generally result in sample means that are approximately normally distributed.

In addition, another limitations of this study is the data collection method. This study adopted a quantitative approach to collecting data through questionnaires. By employing only closed-ended survey questions, this survey limits respondents to a predetermined range of options, thereby limiting their ability to provide insights beyond the choices provided. As a result, the respondents may not be able to provide to a broader perspective and deeper information on the questions.

Furthermore, the outcomes of the study apply only to the construction industry and may not applicable to other industries. This limitation arises from the unique operational dynamics, challenges, and practices inherent to the construction sector, which may vary significantly from other industries. Construction projects often involve complex interactions between various stakeholders, tight timelines, and strict regulatory requirements. Therefore, while the insights gained from this study offer valuable insights and implications for the construction sector, caution should be exercised when applying them to other sectors.

5.5 Research Recommendations

Firstly, it is recommended to allocate a longer time frame for data collection to ensure sufficient time for reaching out to a larger pool of respondents. Recruiting participants can be challenging and time-consuming, especially when the study requires respondents to have specific expertise or experience in BIM or VM practices. Therefore, extending the data collection period allows for more comprehensive sampling of respondents across diverse demographic backgrounds. This allows researchers to obtain a representative sample, which enhances the accuracy of the data analysis and helps draw more reliable conclusions from the study results.

Additionally, in response to the limitations of quantitative method, it is recommended that future research adopt mixed methods. This method involves collecting data by combining quantitative and qualitative approaches. The rankings of variables can be collected through questionnaires, and then interviews with professionals are conducted to verify and confirm the results.

Besides, in-depth and open-ended questions can be used to capture the perspectives of various construction practitioners. This method allows for an in-depth study of variables not mentioned in the questionnaire during the interview process. Therefore, mixed method provides a more comprehensive understanding of the research topic.

Furthermore, it is advisable to conduct similar studies in other industries to validate and extend the findings. Researchers can assess the applicability of the findings and pinpoint industry-specific nuances by conducting similar studies in different industries. By fostering collaboration between various industries, the researchers can exchange knowledge, insights, and best practices related to implementing VM enhancement using BIM. This enables cross-sector learning and helps develop solutions and strategies that meet the needs of various industries. These valuable insights can help the industry grow and further promote widespread adoption of VM enhancement with BIM.

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APPENDICES

Appendix A: Questionnaire

Section A: Demographic Background

1. Which of the following best describes your company's business activity?

- Consultancy
- Contracting Business
- Sub-contracting Business
- Property Development

2. What is your company's size?

- Less than 5 people
- 5 – 30 people
- 31– 75people
- More than 75 people

3. Which of the following best describes your position in the company?

- CEO/ Director
- Contract Manager/ Head of Department
- Assistant Manager/ Team Leader/ Senior Executive
- Junior Executive/ Fresh Graduate

4. Which of the following best describes your profession?

- Quantity Surveyor
- Architect
- Civil & Structural Engineer
- Mechanical & Electrical Engineer
- Builder

5. How many years of working experience do you have in the construction industry?

- 0 - 2 years
- 3 - 5 years
- 6 – 20 years
- 11 – 20 years
- 21 years and above

Section B: Implementing VM with BIM

1. To what extent you agree the followings are implemented in your project?

The Usage of Enhancing VM with BIM	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
a) My company practises post project review whenever the construction project is completed.					
b) My company practises VM/ VE in the construction project.					

c)	My company conducts VM/VE workshops to encourage creative thinking and idea generation.	
d)	We identify and prioritize the key values and objectives for the construction project during the VM/VE process.	
e)	We conduct cost-benefit analysis of the construction project during the VM/VE process.	
f)	My company practises BIM in the construction project.	
g)	The BIM model in my project is used to create visualizations that help clients better understand the project.	
h)	We use BIM tools to monitor the entire building lifecycle.	
i)	We use BIM software to enhance communication and coordination among project stakeholders	
j)	We use available standards (eg: ISO 19650, BIM protocol, etc.) to support BIM management.	
k)	We use BIM software during the VM/VE process.	
l)	We advocate to use BIM in the VM/VE study.	

m)	We make BIM as mandatory for the VM/VE study.

Section C: Advantages of Enhancing VM with BIM

2. To what extent you agree the followings are the advantages of enhancing Value Management with Building Information Modelling in construction industry?

The Advantages of Enhancing VM with BIM	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
a) The enhancement of VM with BIM accelerates project delivery time.					
b) The enhancement of VM with BIM improves collaboration and communication among project stakeholders.					
c) The enhancement of VM with BIM enables precise cost estimation and control.					
d) The enhancement of VM with BIM contributes to energy efficiency and sustainability.					
e) The enhancement of VM with BIM improves work productivity and quality.					
f) The enhancement of VM with BIM enables efficient construction planning and management.					
g) The enhancement of VM with BIM contributes to maintain the construction schedule.					
h) The enhancement of VM with BIM improves the decision-making process for					

	construction projects.
i)	The enhancement of VM with BIM leads to better choices and optimizes project outcomes.
j)	The enhancement of VM with BIM aids in identifying and mitigating risks in construction projects.
k)	The enhancement of VM with BIM helps avoid costly mistakes.
l)	The enhancement of VM with BIM increases client satisfaction.
m)	The enhancement of VM with BIM helps facility management and operation, realizing long-term value for the built environment.

3. To what extent you agree the following advantages are incurred in your on-going/ past construction project?

The Advantages of Enhancing VM with BIM	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
a) The enhancement of VM with BIM accelerates delivery time in my projects.					
b) The enhancement of VM with BIM improves collaboration and communication among project stakeholders in my projects.					
c) The enhancement of VM with BIM enables cost estimation and control in my projects.					
d) The enhancement of VM with BIM improves the energy efficiency and sustainability of my projects.					
e) The enhancement of VM with BIM improves work productivity and the quality of my projects.					
f) The enhancement of VM with BIM enables efficient construction planning and management in my projects.					
g) The enhancement of VM with BIM contributes to maintaining the construction schedule in my projects.					

h)	The enhancement of VM with BIM improves the decision-making process in my projects.
i)	The enhancement of VM with BIM leads to better choices and optimizes project outcomes in my projects.
j)	The enhancement of VM with BIM aids in identifying and mitigating risks in my projects.
k)	The enhancement of VM with BIM helps avoid costly mistakes in my projects.
l)	The enhancement of VM with BIM increases client satisfaction in my projects.
m)	The enhancement of VM with BIM helps facility management and operation, realizing long-term value in my projects.

Section D: Barriers and Strategies of Enhancing VM with BIM

4. To what extent do the following barriers undermine the enhancement of Value Management with Building Information Modelling in your on-going/ past projects?

The Barriers of Enhancing VM with BIM	Never (1)	Rarely (2)	Sometimes (3)	Frequently (4)	All the time (5)
a) High Cost of Implementation					
b) Industry Resistance to Process Change					
c) Lack of Awareness and Understanding					
d) Lack of Legal and Contractual Framework					
e) Lack of Skill and Training					
f) Lack of Interoperability and Data Exchange					
g) Data Privacy and Security Issues					
h) Lack of Standardization					

5. To what extent do you agree the following strategies are effective in encouraging the enhancement of Value Management with Building Information Modelling in your upcoming or on-going project?

The Strategies of Enhancing VM with BIM	Never (1)	Rarely (2)	Sometimes (3)	Frequently (4)	All the time (5)
a) Conduct Conferences and Seminars					
b) Legislation and Government Involvement					
c) Establish a Start-up Funding Mechanism					
d) Provide Professional Training and Promotion Plan					
e) Include VM clauses and BIM in contracts					
f) Cooperation with educational institutions					
g) Standardized BIM implementation process					